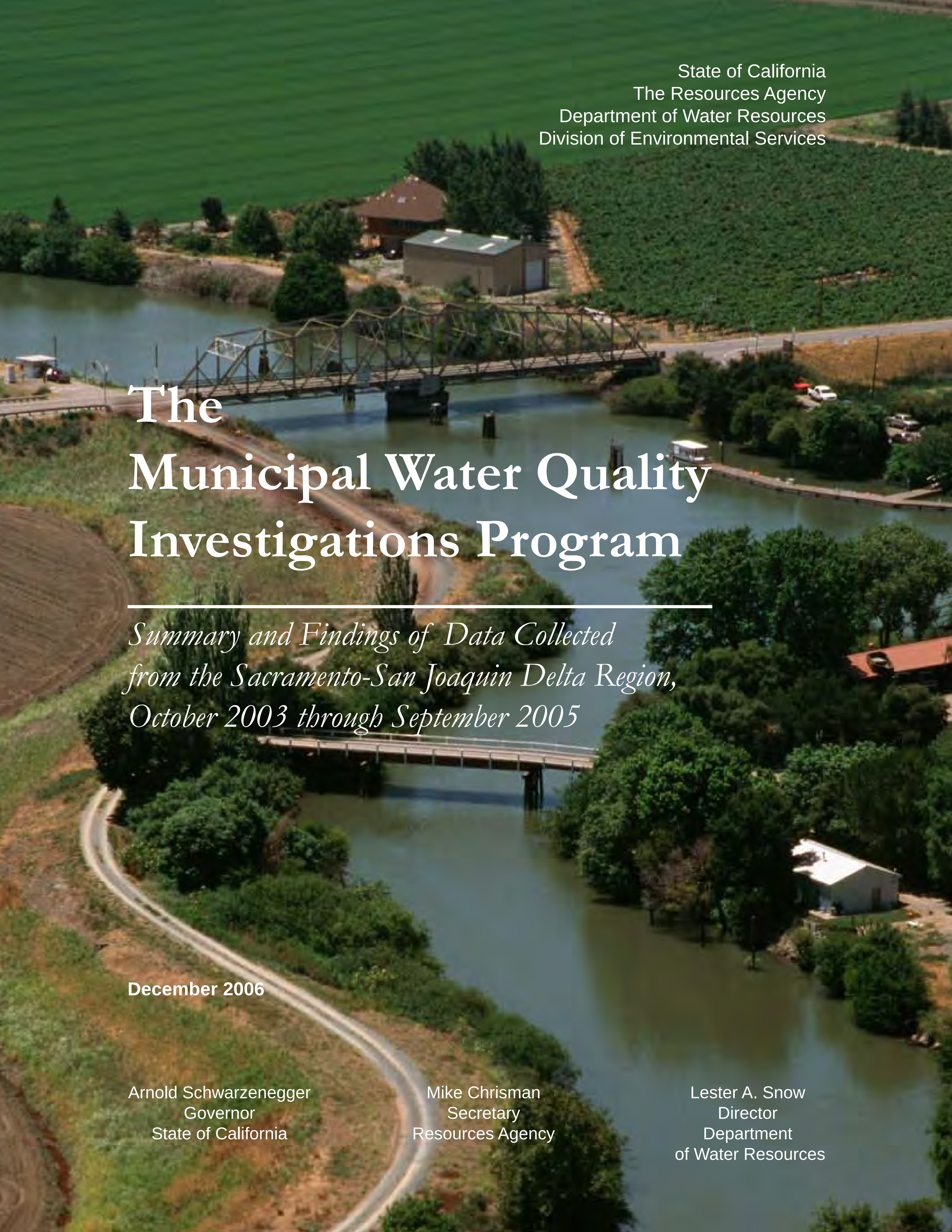

State of California
The Resources Agency
Department of Water Resources
Division of Environmental Services

The Municipal Water Quality Investigations Program

Summary and Findings of Data Collected from the Sacramento-San Joaquin Delta Region, October 2003 through September 2005

December 2006

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Previous editions

The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected August 1998 through September 2001.* (Printed by DWR July 2003)

The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected October 2001 through September 2003.* (Printed by DWR June 2005)

If you need this publication in an alternate form, contact the Municipal Water Quality Investigations Unit at (916) 651-9687 or the Public Affairs Office at 1-800-272-8869.

Foreword

The Sacramento-San Joaquin Delta (Delta) is a major source of drinking water for two-thirds of the population in the State of California. The quality of Delta waters, however, may be degraded by a variety of sources and environmental factors. Close monitoring of Delta waters is necessary to ensure delivery of high quality source waters to urban water suppliers and users of the State.

The Municipal Water Quality Investigations (MWQI) Program of the Division of Environmental Services in the Department of Water Resources is charged with monitoring and research of water quality in the Delta. Among all State and local agencies monitoring the Delta and its tributaries, MWQI conducts the only monitoring program mandated to investigate the quality of source waters in the Delta with respect to its suitability for production of drinking water.

Since 1982, MWQI has been conducting comprehensive and systematic source water monitoring in the Delta region, and regularly prepares annual or multi-year data summary reports. The previous two-year report (June 2005) summarized data collected through September 2003. The current report summarizes and interprets monitoring data collected from October 1, 2003 through September 30, 2005, from 10 MWQI sampling sites. Presented are data and findings for major water quality constituents, including organic carbon, bromide, salinity, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of current interest.

This and other MWQI reports are available online at the MWQI website: www.wq.water.ca.gov/mwqi/mwqi_index.cfm. For further information about the MWQI Program, please visit its website or contact Cindy Messer, Chief of the Municipal Water Quality Investigations Program, (916) 651-9687, or send your request to: MWQI Program, P.O. Box 942836, Sacramento, CA 94236-0001.

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Department of Water Resources Reprographics

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* Data are available on the CD that accompanies the printed version of this report or online where it is posted with the report at DWR's Office of Water Quality Web site:
http://www.wq.water.ca.gov/index.cfm .

Acknowledgments

The authors thank Mr. David Gonzalez, Mr. Steve San Julian, and Mr. Arin Conner for sample collections; Mr. Bill Nickels, Mr. Sid Fong, and the chemists at DWR's Bryte Chemical Laboratory for sample analyses. We thank Mr. Rick Woodard of the State Water Contractors, our colleagues Ms. Karen Enstrom, Ms. Cindy Messer, Mr. Matt Schott, and Mr. Michael Zanoli for reviewing the draft report and providing us with valuable comments. We are particularly grateful to Ms. Marilee Talley for her editorial work, which helped improve the readability of this report. Special thanks are also extended to Ms. Joanne Pierce for modifying the maps in this year's report. We thank Ms. Gretchen Goettl for her enthusiastic support for this project. The MWQI Program gratefully acknowledges support of the following urban water agencies:

State Water Project Contractors:

Alameda County Flood Control and Water Conservation District Zone 7
Alameda County Water District
Antelope Valley-East Kern Water Agency
Castaic Lake Water Agency
Central Coast Water Authority
Crestline-Lake Arrowhead Water Agency
Kern County Water Agency
Metropolitan Water District of Southern California
Mojave Water Agency
Napa County Flood Control and Water Conservation District
Palmdale Water District
San Bernardino Valley Municipal Water District
San Gabriel Valley Municipal Water District
San Gorgonio Pass Water Agency
San Luis Obispo County Flood Control and Water Conservation District
Santa Clara Valley Water District
Solano County Water Agency

MWQI Program Participant:

Contra Costa Water District

Executive Summary

Purpose and Scope

The Municipal Water Quality Investigations (MWQI) Program collects and analyzes water samples from the Sacramento-San Joaquin Delta (the Delta) region and reports its findings to the State Water Contractors and the public through annual or multiyear reports. In this report, we summarize and interpret MWQI discrete (grab) sampling data collected from October 2003 through September 2005. The previous report presented data through September 2003.

Presented are data from 10 MWQI stations. We monitor water quality at four locations on the San Joaquin River (SJR), the Sacramento River, and the American River as they flow into the Delta. Three of these four stations are on the American and Sacramento rivers at or near the north end of the Delta—American River at E.A. Fairbairn Water Treatment Plant (WTP), Sacramento River at West Sacramento WTP Intake, and Sacramento River at Hood. The E.A. Fairbairn WTP represents water quality of the American River, which is a major tributary of the Sacramento River. West Sacramento WTP Intake represents water quality of the Sacramento River before mixing with water of the American River, and the Sacramento River at Hood reflects the quality of water from the Sacramento River shortly after it enters the Delta. The SJR near Vernalis represents SJR water quality as it enters the Delta. In addition, MWQI monitored an urban drainage site—Natomas East Main Drainage Canal, which is just upstream of the northern boundary of the Delta.

Five of the 10 stations are within the Delta or at diversion points in the Delta. Two of the stations—Old River at Station 9 and Old River at Bacon Island—are Delta channel stations representing quality of mixed waters primarily from the SJR and Sacramento River. Water is diverted near Old River at Station 9 at a pumping station belonging to the Contra Costa Water District (CCWD). Two of the 5 stations—Banks Pumping Plant and Contra Costa Pumping Plant #1—are diversion points that reflect the quality of water being diverted from the Delta at these points. The Sacramento River at Mallard Island is a station at the western end of the Delta, which is most susceptible to seawater influence due to its proximity to the San Francisco and Suisun bays.

Water quality constituents in Delta source waters are presented according to current regulatory priorities with organic carbon, bromide, salinity, and nutrients addressed in individual chapters. For each constituent at each station, descriptive plots in the form of temporal graphs show general seasonal patterns. Summary statistics that include range, mean, and median describe general data characteristics.

Summary of Findings

Organic Carbon

Overall, total organic carbon (TOC) measurements were about 15% higher than those of dissolved organic carbon (DOC). American River water had the lowest median TOC of 1.5 mg/L, followed by the other upper Sacramento River stations. Median TOC at Sacramento River at Hood was 1.9 mg/L, which represents organic carbon levels of northern Delta inflows. In contrast, median TOC for the SJR near Vernalis was 3.8 mg/L, which was about twice that of the TOC concentration in the northern inflows. Despite lower organic carbon concentration in northern inflows, median TOC at the 4 Delta channel and diversion stations ranged from 3.1 to 3.4 mg/L, slightly less than that of the SJR near Vernalis suggesting considerable in-Delta sources of organic carbon. Agricultural drainage and in-channel production are probable sources of organic carbon. Compared with the previous 5 water years, median TOC concentrations of most stations did not change significantly. Seasonal patterns of organic carbon concentrations differed between tributary and channel stations. Seasonal patterns at the 4 Delta channel and diversion stations differed from those at SJR and the Sacramento River stations, further indicating in-Delta loads of organic carbon.

Bromide

Bromide concentrations were higher at those stations closer to seawater influence. Of the 10 stations, the Mallard Island station is the closest to the Suisun and San Francisco bays and had the highest median bromide (3.07 mg/L). The SJR near Vernalis had the second highest bromide concentrations with a median of 0.24 mg/L. Elevated bromide in the SJR may be attributable to agricultural drainage returns, which are indirectly influenced by seawater. Median bromide concentrations at the 2 diversion stations were both 0.11 mg/L. Stations at the north end of the Delta are not influenced by seawater; therefore, bromide concentrations were either very low or below the reporting limit of 0.01 mg/L. Compared with the previous 5 water years, median bromide concentrations remained unchanged except at the Contra Costa Pumping Plant #1, where median bromide concentrations were slightly higher, and at the Mallard Island station where median bromide was lower. Data from the current summary period offered additional evidence to support findings of MWQI's previous summary report that bromide in central and western Delta waters originates from seawater.

Salinity

Among the 10 MWQI stations, the lowest electrical conductivity (EC) was found in the American River at E.A. Fairbairn WTP with a median of 63 µS/cm. Median EC at NEMDC was 294 µS/cm, but median flow at NEMDC was less than 1% of the combined flows from Sacramento and American rivers. Median EC at Sacramento River at Hood was 154 µS/cm, which represented salinity in northern Delta inflows. EC of the SJR was much higher than those found in the American or Sacramento rivers. Median EC at SJR near Vernalis was the second highest of the 10 monitored stations. High levels of salts in irrigation returns from the San Joaquin Valley and recirculation of salts from the Delta ultimately increased EC levels in this area. EC was significantly lower in the Delta channel and diversion stations than in the SJR due to the dilution effects of water from the Sacramento River. Median EC at the Delta channel stations was 354 µS/cm for Old River at Station 9 and 339 µS/cm for Old River at Bacon Island. EC was higher at one of the diversion stations, the Contra Costa Pumping Plant #1, where the median was 485 µS/cm. Of all 10 MWQI sampling stations, Mallard Island had the highest salinity concentration because of its proximity to Suisun Bay where tidal events and seawater intrusion to the western Delta occurs. Seawater was the primary source of salinity throughout the western Delta as indicated by the high median EC of 4,190 µS/cm at Mallard Island. From the northern rivers to the SJR and throughout the Delta, salinity is affected by watershed runoff, urban discharges, and agricultural drainage. Seasonal precipitation during wet months and reservoir releases during dry months decrease salinity by diluting this water with low mineral content. However, salinity loads from the watersheds were significant during the wet months, especially after the first few major rain events.

Other Constituents

Also monitored were 11 constituents known to cause adverse effects on human health—aluminum, antimony, arsenic, barium, cadmium, copper, lead, nickel, nitrate, combined nitrate and nitrite, and selenium. Antimony, barium, cadmium, and arsenic were not detected in Delta waters. Of the constituents with secondary standards, those that can adversely affect taste, odor, or appearance of the water, manganese and silver were never detected above their reporting limits. The remaining seven monitored constituents—aluminum, copper, lead, nickel, nitrate, combined nitrate and nitrite, and selenium—were detected at or above the reporting limits; however, they never exceeded federal or State maximum contaminant levels. These federal or State MCLs are applicable to treated drinking water. In many cases, treatment removes or reduces concentrations of regulated substances in finished drinking water.

Acronyms and Abbreviations

af	acre-foot/acre-feet
AL(s)	action level(s)
APHA	American Public Health Association
AWWA	American Water Works Association
BLM	US Bureau of Land Management
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
D/DBP(s)	disinfectant/disinfection byproduct(s)
DES	Division of Environmental Services of DWR
DHS	California Department of Health Services
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DWR	California Department of Water Resources
EC	electrical conductivity
EPA	US Environmental Protection Agency
ESWTR	Enhanced Surface Water Treatment Rule
FLIMS	Field and Laboratory Information Management System
HAAs	Haloacetic acids
IC	Ion Chromatography
ICP	Inductively Coupled Plasma Optical Emission Spectroscopy
IEP	Interagency Ecological Program
IQR	interquartile range
L	liters
LCS	laboratory control sample
maf	million acre-feet
MCL	maximum contaminant level
MDL	method detection limit
mg/L	milligrams per liter
MTBE	methyl tertiary-butyl ether
MWDSC	Metropolitan Water District of Southern California
MWQI	DWR Municipal Water Quality Investigations
NEMDC	Natomas East Main Drainage Canal
nm	nanometers
NTU(s)	nephelometric turbidity unit(s)
O&M	DWR Division of Operations and Maintenance
OWQ	DWR Office of Water Quality

pH	negative log of the hydrogen ion activity
POC	particulate organic carbon
QA/QC	quality assurance/quality control
RPD(s)	relative percent difference(s)
SJR	San Joaquin River
SRWTP	Sacramento Regional Wastewater Treatment Plant
$SUVA_{254}$	specific UVA_{254}
SWC	State Water Contractors
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TCAA	trichloroacetic acid
TDS	total dissolved solids
THM	trihalomethane
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TSS	total suspended solids
TTHMFP	total trihalomethane formation potential
USBR	US Bureau of Reclamation
US EPA	see EPA
UVA_{254}	ultraviolet absorbance measured at a wavelength of 254 nanometers
VAMP	Vernalis Adaptive Management Plan
WDL	Water Data Library
WTP	water treatment plant
WWTP	wastewater treatment plant
WY	water year
µg/L	micrograms per liter
µm	micrometers
µS/cm	microsiemens per centimeter

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

Chapter 1 Introduction

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Chapter 1 Introduction

Scope

This report summarizes and interprets discrete water quality sampling data collected by the Municipal Water Quality Investigations Program (MWQI) of the Department of Water Resources (DWR) from October 1, 2003, to September 30, 2005. This is the third such report within the past 5 years. The previous MWQI report was completed in June 2005 and summarized data collected from October 2001 through September 2003 (DWR 2005).

MWQI = Municipal Water Quality Investigations

DWR = California Department of Water Resources

DWR. 2005. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected Oct 2001 to Sep 2003. June.

Data presented in this report were collected from 10 MWQI stations in or near the Sacramento-San Joaquin Delta (the Delta). An extensive number of water quality constituents were analyzed for each sample. Constituents of most concern to drinking water quality are presented in this report. Selection of constituents is based on findings from previous reports and guidance from the MWQI committee represented by urban State Water Contractors (SWCs). Water quality constituents of limited concern to SWCs are discussed only for selected stations. Major water quality constituents examined in this report include organic carbon, bromide, salinity, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of current interest.

SWCs = State Water Contractors

Statistical data analyses were limited to basic summary statistics and graphs of seasonal patterns for brief discussions on sources and temporal and spatial patterns of some constituents. All raw data (including hydrologic) are available both online and on a CD-ROM accompanying this report (see Appendix B).

Appendix B Data

Although this is an interpretative report, it does not present specific management recommendations based on the data. It remains as a data summary report, which primarily summarizes raw data and presents findings in sufficient detail to describe general source water quality conditions in the Delta. For this reason, this report will not discuss water quality in the context of drinking water standards because source waters are not regulated to meet standards for finished drinking water. At some Delta diversion stations, however, certain constituents are discussed in the context of existing federal or State drinking water regulations and water quality objectives specified in the long-term water supply contracts between DWR and each SWC. This report does not present the details of the regulations, standards, or provisions. Primary maximum contaminant levels (MCLs) for constituents that may be harmful to human health can be found in Title 22 California Code of Regulations (CCR) sections 64431 to 64444. Specific regulations for lead and copper are in section 64670, et seq. Secondary MCLs address the taste, odor, or appearance of drinking water, and are found in 22 CCR section 64449 (source: www.dhs.ca.gov/ps/ddwem/chemicals/MCL/mclindex.htm.) Details of both federal and State laws may be found at the Web sites of the US Environmental Protection Agency and the California Department of Health Services (EPA; DHS). Standard provisions for water supply contract between DWR and SWCs are available from the Project Water Contracts Branch (Web site: http://www.swpao.water.ca.gov/wc_b/), State Water Project Analysis Office of DWR.

MCL = maximum contaminant level

MCLs, DLRs, and Unregulated Chemicals Requiring Monitoring: www.dhs.ca.gov/ps/ddwem/chemicals/MCL/mclindex.htm

DHS Web site: http://www.dhs.ca.gov/ps/ddwem/publications/Regulations/regulations_index.htm

EPA Web site: http://www.epa.gov/safewater/standards.html

State Water Project Analysis Office: http://www.swpao.water.ca.gov/wc_b/

Data presented in this report are from monthly, biweekly, or weekly grab samples. Results and interpretations from grab sampling data, especially monthly data, have limitations in explaining spatial and seasonal patterns in the Delta, given its complex hydrology. MWQI efforts are under way to collect real-time data to enable model-assisted forecasting of water quality conditions in this region. Significant progress has been made by DWR modelers and MWQI staff to make this data available to the public via an electronic weekly update to SWCs and the public (Web site: wqdev5.water.ca.gov/mwqi/RTDF/RTDF_weekly.cfm). To be included on the distribution list for receipt of this report, contact Dr. Ted Swift at swift@water.ca.gov. Models used in this effort may be found at the Web site of the Modeling Support Branch, Bay-Delta Office of DWR (Web site: baydeltaoffice.water.ca.gov/modeling/).

Monitoring Stations and Sampling Frequency

Geographic locations of the 10 monitoring stations are presented in Figure 1-1. MWQI staff collected samples at 9 of these stations; Division of Operations and Maintenance (O&M) staff collected samples for MWQI at the Banks Pumping Plant.

Samples generally were collected either monthly or biweekly (Table 1-1), but weekly samples were collected at 6 stations during the wet months of the 2004 water year (WY). These weekly samples were analyzed for turbidity, electrical conductivity (EC), alkalinity, total organic carbon (TOC), dissolved organic carbon (DOC), and bromide. Biweekly samples were collected during the 2004 and 2005 water years at 2 key stations: the Hood station on the Sacramento River and the San Joaquin River (SJR) near Vernalis station. These biweekly samples were scheduled with the regular real-time equipment maintenance trips to both stations. In addition to regular weekly or monthly sampling, event-based sampling occurred at the Natomas East Main Drainage Canal (NEMDC).

For this report, the 10 sampling stations were divided into 5 groups for discussion purposes (see Table 1-1). Stations within each group are either geographically or hydrologically related. The NEMDC station, which is an urban drainage tributary to the Sacramento River, is the subject of an on-going MWQI special study. A special report and technical manuscript is currently being developed from data collected at this station, thus NEMDC data will not be presented in great detail in this report.

The Mallard Island station traditionally is considered a station on the Sacramento River. However, it receives water from both the SJR and the Sacramento River, and it is affected by waters from the San Francisco and Suisun bays. The Mallard Island station shows the most seawater influence of all the Delta stations monitored through the MWQI Program. When Delta outflows are low during dry runoff years or during dry months of each year, water quality (EC and bromide in particular) at this station reflects a mixture of fresh and marine waters and, thus, is an indicator of water quality that may be affecting Delta diversion stations. Water quality at this station is discussed separately throughout this report.

MWQI Real Time Data & Forecasting
wqdev5.water.ca.gov/mwqi/RTDF/RTDF_weekly.cfm

To be included on distribution list for this report, contact Dr. Ted Swift at swift@water.ca.gov

Modeling Support Branch
baydeltaoffice.water.ca.gov/modeling/

Figure 1-1 MWQI discrete sampling stations, Oct 1, 2003 to Sep 30, 2005

O&M = Division of Operations and Maintenance

Table 1-1 MWQI discrete sampling station information, 2001–2003

WY = water year

EC = electrical conductivity

TOC = total organic carbon

DOC = dissolved organic carbon

SJR = San Joaquin River

NEMDC = Natomas East Main Drainage Canal

Program Changes

During the reporting period, monitoring frequency at 6 stations was increased from monthly to weekly from November 1, 2003, to April 30, 2004. The increased monitoring served as a temporary alternative to real-time carbon and anion data while awaiting construction and installation of planned real-time monitoring facilities at these key stations. For the weekly samples, turbidity, EC, alkalinity, TOC, DOC, and bromide were analyzed. The standard minerals were not included in the weekly samples because historical data have shown these parameters are of less concern in Delta source waters and monthly sampling data are sufficient.

When construction of the MWQI real-time station at the SJR near Vernalis was completed and went into operation May 1, 2005, real-time EC and organic carbon data became available at 3 key stations: Sacramento River at Hood, SJR near Vernalis, and the Banks Pumping Plant. Weekly sampling was then discontinued. Biweekly sampling continued at both Hood and Vernalis and was scheduled with real-time equipment maintenance trips to both stations.

Sample Collection and Laboratory Analysis

Sample collection and laboratory analytical methods remained unchanged since the release of the last MWQI data report. Detailed sample collection procedures and laboratory methods can be found with the previous MWQI report (DWR 2005). Two tables are reproduced here for the convenience of the readers (Tables 1-2 and 1-3).

Table 1-2 MWQI water sample collection and preservation requirements

Table 1-3 Analytical methods and reporting limits for included constituents

Data Quality

Once analyses were completed, the remaining samples were stored for 30 to 60 days before being discarded. Sample retention is necessary for evaluating and ensuring valid data. Bryte Laboratory follows a set of internal quality assurance/quality control (QA/QC) audit procedures, which include evaluation of blanks (laboratory and field), calibration standards, and laboratory control samples. The detailed QA/QC procedures and corrective actions have been described in Bryte Laboratory's latest QA technical documentation (Fong and Aylesworth 2006). The QA/QC Unit of the Office of Water Quality performs data quality checks routinely on data in the Water Data Library (WDL), a database for storing MWQI data. Results of data quality evaluations for constituents included in this report are presented in Chapter 8.

QA/QC = quality assurance/quality control

Fong and Aylesworth. 2006. Bryte Chemical Laboratory Quality Assurance Manual. Sacramento: DWR, Environmental Services Division, Water Quality Assessment Branch, Bryte Chemical Laboratory. May.

WDL = Water Data Library

In this report, constituents at concentrations below their reporting limits are treated as a "nondetect" and are not included in the summary statistics (discussed below). During the reporting period, occasional method changes occurred for some constituents due to adoption of improved techniques, equipment failures, or other resource limitations. Constituents that may be analyzed by more than one method are shown in Table 1-3. To minimize discrepancy of data resulting from method changes, this report attempted to include data from a single method for each constituent if a complete data set was available for the reporting period; otherwise, data from 2 methods were combined if the 2 methods were comparable and noted in Appendix B.

Statistical Analysis

The following summary statistics will be presented in tabular form for each constituent:

- Data range: data span from the minimum to the maximum.
- Mean: presented mostly for historical reasons. Skewed data of wide variability such as water quality data should not be averaged because the mean is usually strongly influenced by data at both ends and is often misleading.
- Median: a more robust measure for central tendency of water quality data, thus a generally preferred measure over the mean.

Water quality data for included constituents were generally not normally distributed, thus parametric statistical methods may not be robust. Therefore, some nonparametric comparisons were made. When necessary, a nonparametric test—the Mann-Whitney test—was used for comparisons of medians among stations or among different time periods. This distribution-free test is as powerful as its parametric equivalents for most water quality data, but does not require normal data distribution or data transformation.

Most data are presented in descriptive plots. Summary statistics were computed using Microsoft Excel. Nonparametric statistical comparisons were made using Minitab, Release 14.

Descriptive Plots

Descriptive plots are mostly in the form of temporal graphs. Monthly, biweekly, or weekly data were plotted with time to demonstrate general behavior of the data during the reporting period. Data interpretations are based generally on these plots for seasonal differences, which demonstrate the influences of constituent sources during a given time period.

Frequently Used Terms and Abbreviations

This report uses certain terminologies, acronyms, and abbreviations. A complete list is at the front of this report. Some frequently used terms and abbreviations are defined here:

Banks Pumping Plant: Harvey O. Banks Pumping Plant Headworks monitoring station at the start of the California Aqueduct

Contra Costa Pumping Plant (CCPP#1): Contra Costa Water District Pumping Plant #1

Dry months: May 1 to October 31 of each calendar year

Dry year, below normal year, and above normal year: Runoff year types indicating low, moderately high, and high total unimpaired runoff in a watershed, respectively, as defined in cdec.water.ca.gov/cgi-progs/iodir/wsihist.

California Data Exchange Center
cdec.water.ca.gov/cgi-progs/iodir/wsihist

NEMDC: Natomas East Main Drainage Canal

***p*-value and statistical significance:** In this report, the *p*-value, or *p* in short, is reported whenever a statistical comparison is made. The *p*-value is a computed probability value used in combination with a prescribed level of significance (α) to declare if a test is statistically significant. The smaller the *p*-value, the stronger is the evidence supporting statistical significance. This report uses a commonly accepted α value of 5%, or $\alpha = 0.05$. If the *p*-value is < 0.05, the statistical test is declared significant; otherwise, the test is declared not statistically significant.

Reporting period/Summary period: This is the period from October 1, 2003, to September 30, 2005, which includes 2 water years (i.e., the 2004 and 2005 water years). Thus, "the reporting period" or "the summary period" may also be referred to as "the 2 water years" throughout the report.

SJR: San Joaquin River

TKN: Total Kjeldahl nitrogen includes organic nitrogen and ammonia but excludes the oxidized nitrogen species, nitrate and nitrite.

VAMP: Vernalis Adaptive Management Plan is mandated by State Water Resources Control Board Decision 1641. From April 15 to May 15, reservoir releases to the SJR are increased. Diversions are reduced and temporary barriers are installed to increase the survival of juvenile Chinook salmon in their migration to the ocean.

Water year or WY: In California, the period from October 1 of one calendar year to September 30 of the following calendar year is defined as a water year. The water year number is the latter of the 2 calendar years; for example, 2004 WY runs from October 1, 2003, to September 30, 2004.

Wet months: November 1 to April 30 of each water year.

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Figure

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Figure 1-1 MWQI discrete sampling stations, October 1, 2003, to September 30, 2005

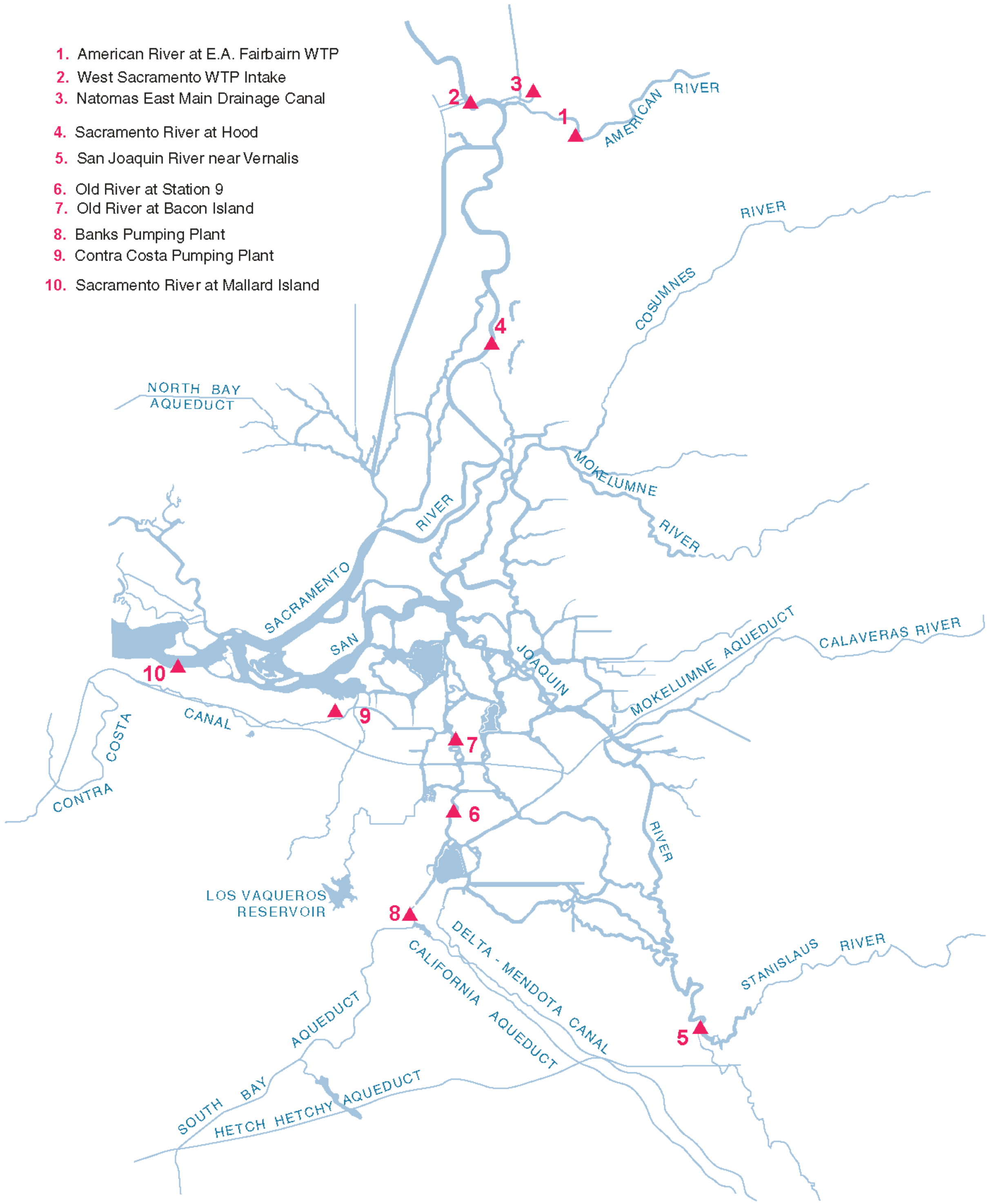

Table 1-1 MWQI discrete sampling station information, 2001–2003

Station	DWR station number	Monitoring frequency
Stations north of the Delta		
American River at E.A. Fairbairn WTP[a]	A0714010	Monthly / weekly (Nov-April) [b]
Sacramento River at West Sacramento WTP Intake	A0210451	Monthly / weekly (Nov-April)
Natomas East Main Drainage Canal	A0V83671280	Monthly / event-based [c] (Nov-April)
Sacramento River at Hood	B9D82211312	Weekly
San Joaquin River near Vernalis	B0702000	Weekly
Delta channel and diversion stations		
Old River at Station 9	B9D75351342	Monthly / weekly (Nov-April)
Old River at Bacon Island	B9D75811344	Monthly / weekly (Nov-April)
Banks Pumping Plant	KA000331	Monthly
Contra Costa Pumping Plant	B9591000	Monthly
Mallard Island station	E0B80261551	Monthly

a. WTP = water treatment plant.
b. Weekly sampling from November through April for turbidity, electrical conductivity, alkalinity, TOC, DOC, and bromide.
c. Monitoring approximately weekly depending on storm events.

Table 1-2 MWQI water sample collection and preservation requirements

Constituent	Container	Sample preparation	Sample size (mL)	Preservative	Holding time
Alkalinity	Polyethylene	Filtered	500	4 ^oC	14 days
Electrical conductivity (EC)	Polyethylene	Filtered	500	4 ^oC	28 days
Hardness by calculation	Polyethylene	Filtered	250	HNO_3, pH<2	6 months
Hardness, total by calculation	Polyethylene	Unfiltered	250	HNO_3, pH<2	6 months
ICP cations, dissolved - Na,Ca,Mg, K, B, Si	Polyethylene, acid washed	Filtered	250	HNO_3, pH<2	6 months
ICP cations, total - Na,Ca,Mg, K, B, Si	Polyethylene, acid washed	Unfiltered	250	HNO_3, pH<2	6 months
ICP/MS trace metals, dissolved	Polyethylene, acid washed	Filtered	500	HNO_3, pH<2	6 Months
ICP/MS trace metals, total	Polyethylene, acid washed	Unfiltered	500	HNO_3, pH<2	6 Months
IC anions - Cl, SO_4, Br, F	Polyethylene	Filtered	500	4 ^oC	28 days
Mercury by cold vapor	Polyethylene, acid washed	Unfiltered	500	4 ^oC, HNO_3, pH<2	28 days
Mercury by ICP/MS	Polyethylene, acid washed	Filtered	500	4 ^oC, HNO_3, pH<2	28 days
Nitrate, nitrite (nutrient)	Polyethylene	Filtered	250	-20 ^oC, dark	48 hours
Nitrate, nitrite (nutrient DWR Modified)	Polyethylene	Filtered	250	-20 ^oC, dark	28 days
Nitrate, nitrite (Std Mineral-IC Anions)	Polyethylene	Filtered	500	4 ^oC	48 hours
Nitrate, nitrite (Std Mineral DWR Modified)	Polyethylene	Filtered	500	4 ^oC	28 days
Nitrogen, ammonia	Polyethylene	Filtered	250	-20 ^oC, dark	28 days
Nitrogen Kjeldahl, total (TKN)	Polyethylene	Unfiltered	250	-20 ^oC, dark	28 days
Organic carbon, dissolved (DOC)	Glass, clear VOA	Filtered	40	4 ^oC, HNO_3, pH<2	28 days
Organic carbon, total (TOC)	Glass, clear VOA	Unfiltered	40	4 ^oC, HNO_3, pH<2	28 days
Orthophosphate	Polyethylene	Filtered	250	4 ^oC	48 hours
Orthophosphate DWR modified	Polyethylene	Filtered	250	-20 ^oC, dark	28 days
pH	Polyethylene	Unfiltered	250	4 ^oC	ASAP

Table continued on next page

Table 1-2 continued

Constituent	Container	Sample preparation	Sample size (mL)	Preservative	Holding time
Phosphorous, total	Polyethylene	Unfiltered	250	-20 ^{o}C, dark	28 days
Solids, total dissolved (TDS)	Polyethylene	Filtered	500	4 ^{o}C	7 days
Turbidity	Polyethylene	Unfiltered	500	4 ^{o}C	48 hours
UVA	Polyethylene	Filtered	250	4 ^{o}C	14 days
Volatile organic analysis (MTBE, etc.)	Glass, amber VOA	Unfiltered	40, X 2, Teflon, no air	4 ^{o}C, HCl, pH<2	14 days

Note: Condensed from Appendix A, *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

Table 1-3 Analytical methods and reporting limits for included constituents

Constituent	Method source [a]	Method number	Reporting limit [b]
Total organic carbon (TOC)	Std Methods	5310-D, Wet oxidation, IR, automated	0.1
	EPA	415.1 Wet oxidation, IR, automated	0.1
Dissolved organic carbon (DOC)	EPA	415.1 Wet oxidation, IR, automated	0.1
UV absorbance at 254 nm	Std Methods	5910-B UV-absorbing organics	0.001 cm^{-1}
Bromide		300.0 ion chromatography	0.01
Electrical conductivity (EC)	Std Methods	2310-B Wheatstone Bridge	1 µS/cm
	EPA	120.1 Wheatstone Bridge	1 µS/cm
Total dissolved solids (TDS)	Std Methods	2540-C Gravimetric, dried at 180° C	1
	EPA	160.1 Gravimetric, dried at 180° C	1
Chloride	Std Methods	4500-Cl-E Colorimetric, Ferricyanide	1
Sulfate		375.2 Colorimetric, Methythymol Blue	1
		300.0 Ion Chromatography	1
Calcium	EPA	215.1AA Flame	1
		200.7 ICP	1
Magnesium		242.1 AA Flame	1
		200.7 ICP	1
Sodium		273.1 AA Flame	1
		200.7 ICP	1
pH	Std Methods	2320-B Electrometric	0.1 pH unit
	EPA	150.1 Electrometric	0.1 pH unit
Alkalinity	Std Methods	2320-B Titrimetric	1
	EPA	310.1 Titrimetric	1
Hardness	Std Methods	2340 B total by calculation	
Turbidity		2130-B Nephelometric	1 NTU
	EPA	180.1 Nephelometric	1 NTU

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

a. Std Methods = "Standard Methods for the Examination of Water and Wastewater," 1995. 19th ed. Eaton AD, Clesceri LS, Greenberg AE, Franson MAH, editors. Prepared and published jointly by American Public Health Association, American Water Works Association, Water Environment Federation. Washington, DC: American Public Health

b. Unit is mg/L unless otherwise indicated.

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Table 1-3 continued

Constituent	Method source [a]	Method number	Reporting limit [b]
Aluminum	EPA	200.7 ICP	0.05
		200.8 ICP/MS	0.01
		200.9 GFAA	0.01
Antimony	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
Arsenic	Std Methods	3114 (4d), AA gaseous hydride	0.001
	EPA	200.7 ICP	0.05
		200.8 ICP/MS	0.001
Barium	EPA	200.7 ICP	0.01
		200.8 ICP/MS	0.05
		200.9 GFAA	0.05
		208.2 GFAA	0.05
Boron	USGS	I-2115-85 Colorimetric, Azomethine	0.1
Cadmium	EPA	200.7 ICP	0.01
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		213.2 GFAA	0.005
Total chromium (all valencies)	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		218.2 GFAA	0.005
Cobalt	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		219.2 GFAA	0.005
Copper	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		220.1 AA Flame	0.1
		220.2 GFAA	0.005

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).
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b. Unit is mg/L unless otherwise indicated.

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Table 1-3 continued

Constituent	Method source[a]	Method number	Reporting limit[b]
Iron	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		236.1 AA Flame	0.1
		236.2 GFAA	0.005
Lead	EPA	200.7 ICP	0.05
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		239.2 GFAA	0.005
Manganese	EPA	200.7 ICP	0.01
		200.9 GFAA	0.005
		243.1 AA Flame	0.1
		243.2 GFAA	0.005
Mercury	EPA	245.1 AA, Flameless, cold vapor	0.001
Molybdenum	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		246.2 GFAA	0.005
Nickel	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		249.1 AA Flame	0.1
		249.2 GFAA	0.005
Selenium	Std Methods	3114B AA gaseous hydride	0.001
	EPA	200.8 ICP/MS	0.001
Silver	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		272.2 GFAA	0.005

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).
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b. Unit is mg/L unless otherwise indicated.

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Table 1-3 continued

Constituent	Method source [a]	Method number	Reporting limit [b]
Zinc	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		289.1 AA Flame, Direct	0.1
		289.2 GFAA	0.005
Ammonia	Std Methods	4500-NH_3 B, G Automated Phenate	0.01
	EPA	350.1 Automated Phenate	0.01
Total Kjeldahl nitrogen	EPA	351.2 Colorimetric, semi-automated	0.1
Nitrate	Std Methods	4500-NO_3-F Cd-Reduction	0.01
	EPA	353.2 Cd-Reduction, Automated	0.01
Nitrite + nitrate	EPA	353.2, Cd-Reduction, Automated	0.01
Orthophosphate	Std Methods	4500-P-E Colorimetric, Ascorbic Acid	0.01
	EPA	365.1 Colorimetric, Ascorbic Acid	0.01
Phosphorus, total	EPA	365.4 Colorimetric, semi-automated	0.01

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

a. Std Methods = “Standard Methods for the Examination of Water and Wastewater,” 1995. 19th ed. Eaton AD, Clesceri LS, Greenberg AE, Franson MAH, editors. Prepared and published jointly by American Public Health Association, American Water Works Association, Water Environment Federation. Washington, DC: American Public Health

b. Unit is mg/L unless otherwise indicated.

Chapter 2 Watershed and Delta Hydrology

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Chapter 2 Watershed and Delta Hydrology

Water quality in the Delta is affected by the hydrology of the Delta as well as the hydrologic conditions of the watersheds that contribute water to it. Data presented in this chapter include inflows from the 2 major rivers, releases from the larger reservoirs, precipitation in the watersheds, and the calculated total Delta outflow. Hydrologic classification indices are also presented for both watersheds for water years 2001 through 2005.

Sacramento River Basin

The watershed of the Sacramento River is greater than 26,000 square miles and is the largest in the state. The major tributaries are the Pit, McCloud, Feather, Yuba, and American rivers. Although it is not a tributary, some of the Trinity River flow is diverted to the Sacramento.

Flow in the Sacramento originates as runoff from 6 major areas. These are the Sacramento Valley and the Modoc Plateau plus the mountainous areas of the Coast Range, Klamath Mountains, Cascade Range, and Sierra Nevada. Most of the population in this watershed as well as the majority of agricultural land is in the Sacramento Valley; therefore, the greatest use of water for domestic supply and agricultural purposes is in this area.

Precipitation in the Central Valley of California occurs primarily in the winter and spring. Because demand for water is greater in the summer and fall, it is fortunate that much of the precipitation at higher elevations occurs as snow. In this way, these areas act as secondary reservoirs holding the water for later use. In addition, the major reservoirs in the watershed have a total capacity of approximately 10 million acre-feet.

San Joaquin River Basin

Although the San Joaquin River (SJR) has a much smaller watershed than the Sacramento, it is still the second largest river in the state with a watershed of approximately 15,200 square miles. The major tributaries are the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes rivers. The San Joaquin and all its major tributaries have their origin in the Sierra Nevada, and they all have reservoirs located above the San Joaquin Valley. There are 9 reservoirs with a capacity equal to or greater than 100,000 acre-feet, and their total capacity is 7.44-million acre-feet.

SJR = San Joaquin River

Precipitation in the Sacramento and San Joaquin Valleys

Figure 2-1 Location of selected weather stations

Data from 3 weather stations in each valley are presented in this chapter, and the locations of these stations are shown in Figure 2-1. Stations in the Sacramento Valley include Redding Fire Station, Durham, and California State University at Sacramento. Stations in the San Joaquin Valley are Brentwood, Stockton Fire Station, and Madera.

Data for these stations were obtained from 2 sources, the California Data Exchange Center (CDEC) and California Irrigation Management Information System (CIMIS). CDEC provided data for the Redding Fire Station, Stockton Fire Station, and Sacramento State University stations. CIMIS provided data for the Durham, Brentwood, and Madera stations.

CDEC = California Data Exchange Center

CIMIS = California Irrigation Management Information System

In both the 2004 and 2005 water years, precipitation was significantly higher in the Sacramento River watershed than in the San Joaquin (Tables 2-1 and 2-2 and Figure 2-2). In both years, precipitation for the 3 stations in the Sacramento watershed was more than twice that of the San Joaquin watershed. The rainfall pattern was typical, with most occurring during the late fall through early spring and little to none in the summer.

Table 2-1 Summary of daily precipitation (inches) at six weather stations

Table 2-2 Summary of monthly precipitation (inches) at six weather stations

Figure 2-2 Cumulated monthly precipitation at six stations

The number of rainy days during the reporting period was the greatest at the Redding Fire Station with 198 days. This station also had the greatest annual rainfall with 46.20 inches and 51.44 inches during the 2 consecutive years. It was also the only station with daily totals greater than 2 inches. In the SJR watershed, the total annual precipitation at the Stockton Fire Station was nearly the same as that at the Brentwood station in both years (see Table 2-2). The intensity, however, was considerably different as shown by the number of rainy days at each station. There were 113 days with rain at Stockton, but 171 rainy days at the Brentwood station (see Table 2-1).

WY = water year

At all stations the annual total precipitation for the 2005 water year was greater than the total for the 2004 WY. The maximum difference occurred at the Stockton Fire Station where the 2005 WY total was 152% of the 2004 WY. The minimum difference was at the Redding Fire Station where the 2005 WY total was 111% of the 2004 WY total.

Water Year Classification

The classification of water years is done using a system developed by the State Water Resources Control Board. The method is found in Water Rights Decision 1641, revised March 15, 2000 (SWRCB 2000). Under this system there are 5 water year types based on the amount of unimpaired runoff at key stream stations in the watersheds of the Sacramento River and the SJR. These year types are: wet, above normal, below normal, dry, and critical.

SWRCB. 2000. Water Right Decision 1641 (revised). www.waterrights.ca.gov/baydelta/d1641.htm

The Sacramento Valley water year types were below normal in 2004 WY and above normal in 2005 WY (Table 2-3). The water year types for the San Joaquin Valley were dry in 2004 WY and wet in 2005 WY (see Table 2-3).

Table 2-3 Hydrologic index classification based on measured unimpaired runoff at selected rivers

Releases from Reservoirs

Central Valley reservoirs furnish water for both agricultural and domestic uses. Millions of people in California receive a high percentage of their household water from these reservoirs, and approximately 4-million acres of cropland are irrigated with water from these sources. Because most of the precipitation occurs in a 6-month period, these reservoirs are needed to supply water on a year-round basis.

Sacramento Valley

The major reservoirs that provide water to the Sacramento River are presented in Figure 2-3. Shasta Reservoir release data include water imported from the Trinity River. The combined releases from both Oroville and New Bullards Bar reservoirs are included in the second (white) bar, Folsom Lake releases are presented in the third (gray) bar.

Figure 2-3 Sacramento River watershed reservoir releases

Although 2004 WY was classified as below normal and 2005 WY was above normal, the total releases from the major reservoirs in the Sacramento Valley were greater in 2004 WY. This was perhaps because more reservoir water was necessary to compensate for less watershed runoff in order to meet total

Delta outflow demands during the dry months of 2004 WY. Reservoir releases were approximately 14.9 million acre-feet in 2004 WY and approximately 12.2 million acre-feet in 2005 WY.

San Joaquin Valley

Release data from 6 major reservoirs in the SJR watershed are presented in Figure 2-4. Data from New Melones, New Hogan, and Camanche reservoirs are included in the top graph. The bottom graph includes data from Millerton Lake, Lake McClure, and Don Pedro Reservoir. Total releases from these reservoirs for the 2 water years were much lower than those from reservoirs in the Sacramento River watershed. The total release for the 2004 WY was approximately 4.2 million acre-feet, and the total for 2005 WY was approximately 7.8 million acre-feet.

Figure 2-4 San Joaquin River watershed reservoir releases

Delta Outflows

The Sacramento River and the SJR and their tributaries provide fresh water inflow to the Delta. Within the Delta, diversions of water reduce the amount of fresh water that flows out of the Delta and into the Suisun and San Francisco bays. Besides water used locally for irrigation, there are three major diversions that take water out of the Delta including the State Water Project (SWP), the Delta Mendota Canal, and Contra Costa Water District. The latter 2 diversions are part of the Central Valley Project (CVP).

SWP = State Water Project

CVP = Central Valley Project

Water that is not diverted or does not evaporate from the channels flows out of the Delta and into the bays. The lower the outflow, the more the tides increase the salinity of Delta waters. It is difficult to measure Delta outflow directly. Presently, Delta outflows are being determined by calculation. The calculated outflows and the inflows of the Sacramento and San Joaquin Rivers are presented in Figure 2-5. The outflows tend to be lowest in the late summer and early autumn.

Figure 2-5 Delta total outflow and major river inflows, 2004 and 2005 water years

Delta Cross Channel Operations

The Delta Cross Channel is a gated channel that connects the Sacramento River to Snodgrass Slough, which opens into the Mokelumne River. It is a facility of the US Bureau of Reclamation and is operated in accordance with State Water Resources Control Board Decision 1641 (SWRCB 2000). When the gates are open, water from the Sacramento River has a more direct route and shorter distance to the major diversion pumps in the southern Delta. This, therefore, improves the quality of water being diverted by lowering the electrical conductivity (EC) and salinity.

EC = electrical conductivity

The gates are closed during fish migration to avoid confusing migrating fish. They are also closed during high flows in the Sacramento River to reduce flood risks along the Mokelumne River and lower SJR. The timing of the opening and closing of the gates depends on the period of fish migration and the flows in the Sacramento River (Table 2-4).

Table 2-4 Delta Cross Channel operations

Vernalis Adaptive Management Plan

The Vernalis Adaptive Management Plan (VAMP) is an annual program that is conducted to increase the survival of migrating juvenile Chinook salmon smolts in their travel down the San Joaquin River to the ocean. The normal VAMP period is from April 15 through May 15, but it can be a different 31-day period based on the time of the migration. In years of lower flows, releases from the major reservoirs in the San Joaquin watershed are increased. At the same time, combined pumping at the Banks and Tracy pumping plants are reduced to 1,500 cubic feet per second (cfs). In years of higher flows, the combined pumping can be higher. Because the VAMP program is adaptively managed and adjusted based on the hydrology in the particular year, specific levels of pumping corresponding to various levels of flow cannot be forecast until the spring of that year.

VAMP = Vernalis Adaptive Management Plan

cfs = cubic feet per second

In addition to the limited pumping during VAMP, a temporary barrier is constructed at the head of Old River. This causes the migrating smolts to follow the SJR through the Delta, and it considerably reduces the number lost as a result of SWP and CVP diversions.

In the 2004 WY, mean daily flow in the SJR was 2,057 cfs on the day before VAMP began, and EC was 537 µS/cm. Five days later flow had increased to 3,102 cfs, and EC had decreased to 351 µS/cm. For the entire period the average flow was 3,157 cfs, and EC was 345 µS/cm.

SJR flow was higher in the 2005 WY and did not need to be augmented with additional reservoir releases. Releases were increased later in the period for other reasons. Flow was 7,359 cfs at the start of the VAMP period, and it was 15,775 cfs at the end. The EC started at 250 µS/cm and ended at 100 µS/cm.

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Figure 2-1 Location of selected weather stations

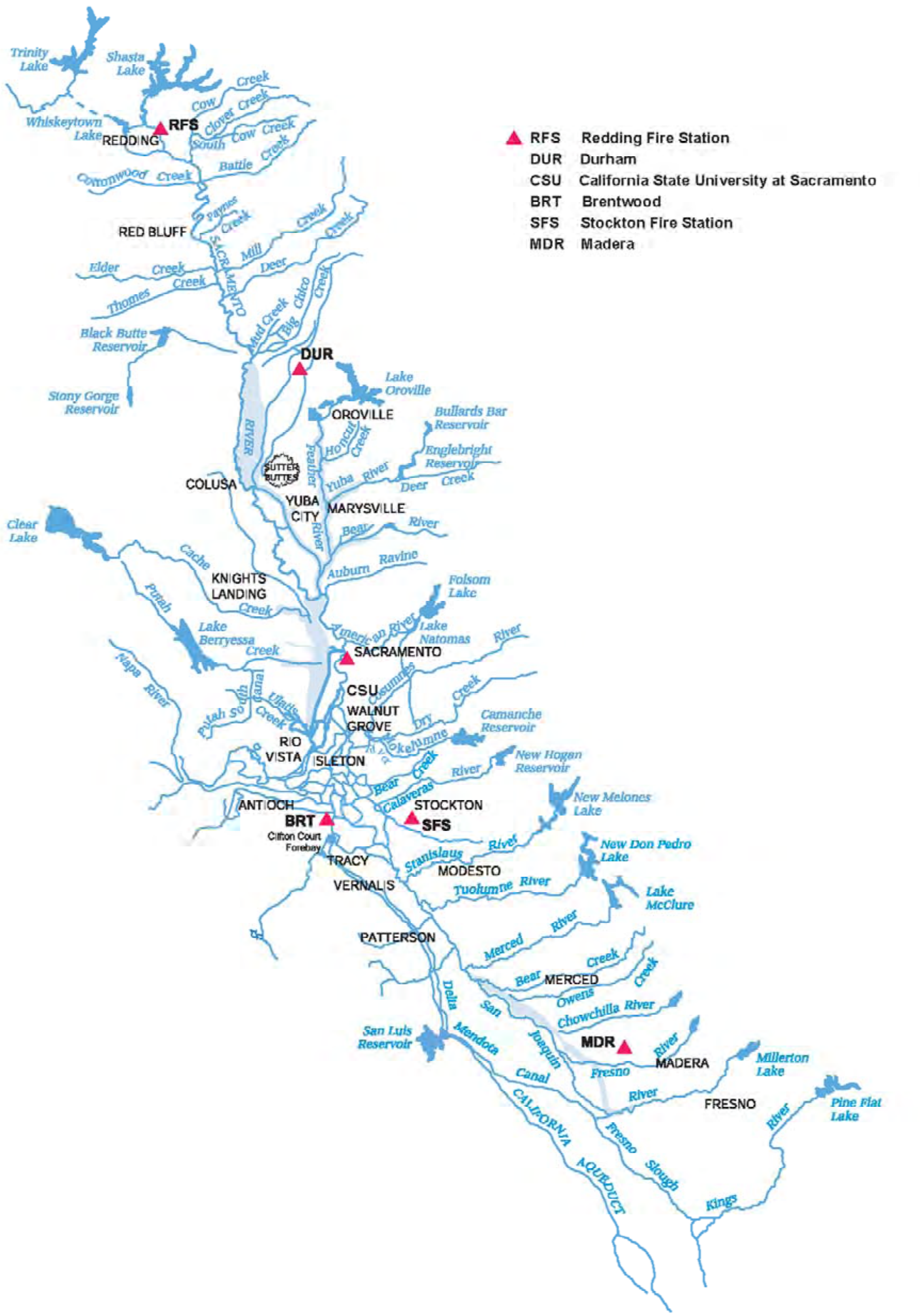

Figure 2-2 Cumulated monthly precipitation at six stations

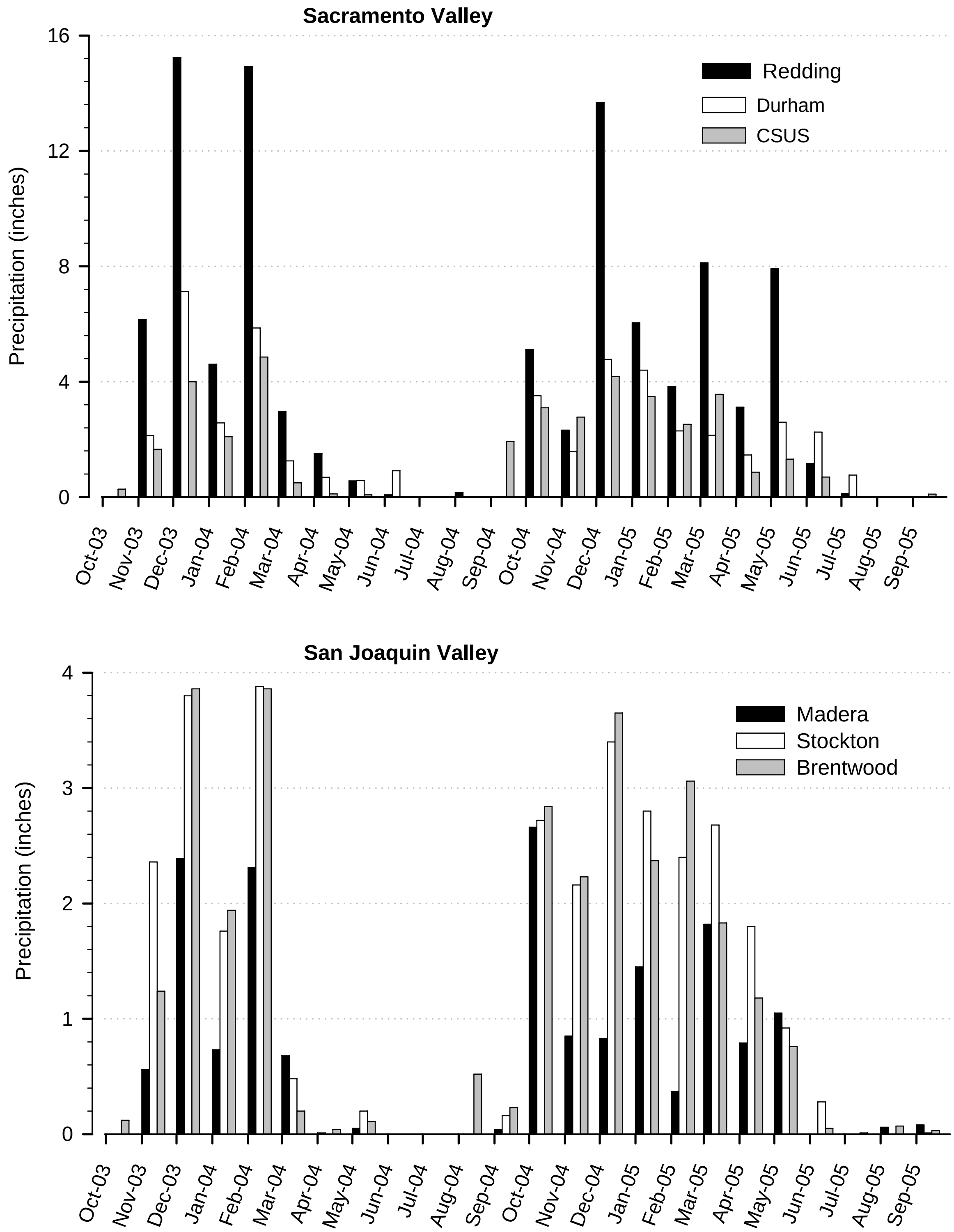

Figure 2-3 Sacramento River watershed reservoir releases

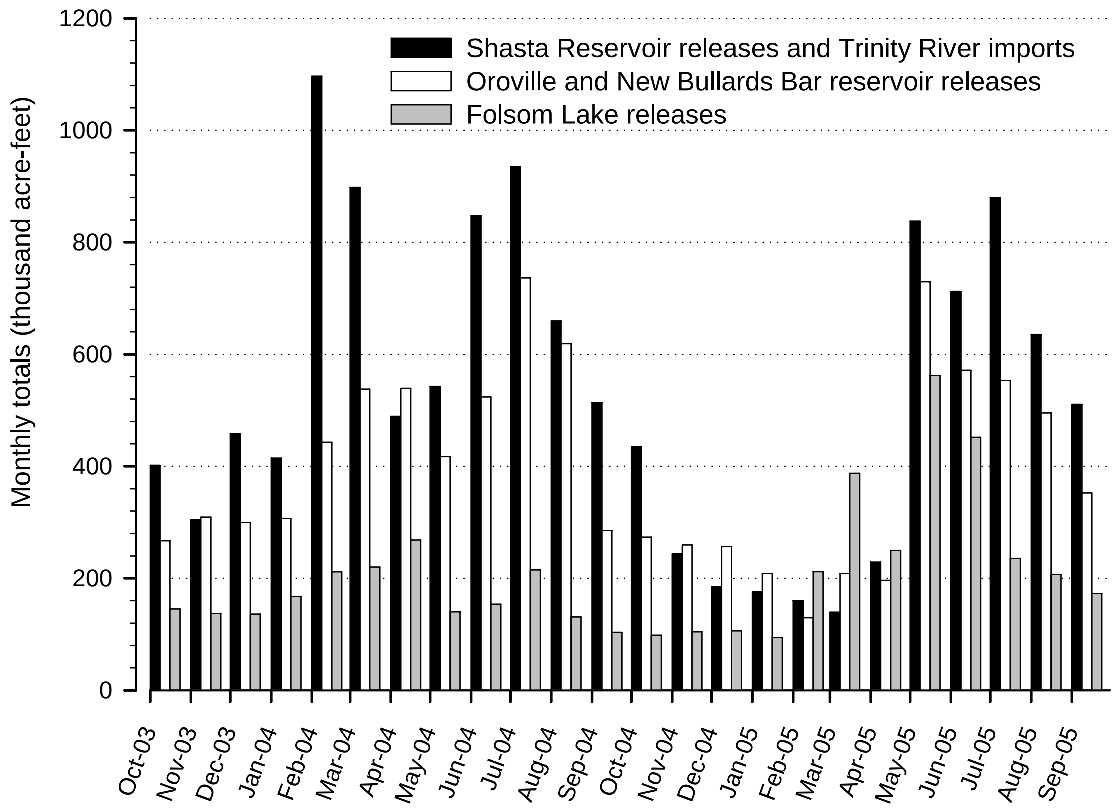

Figure 2-4 San Joaquin River watershed reservoir releases

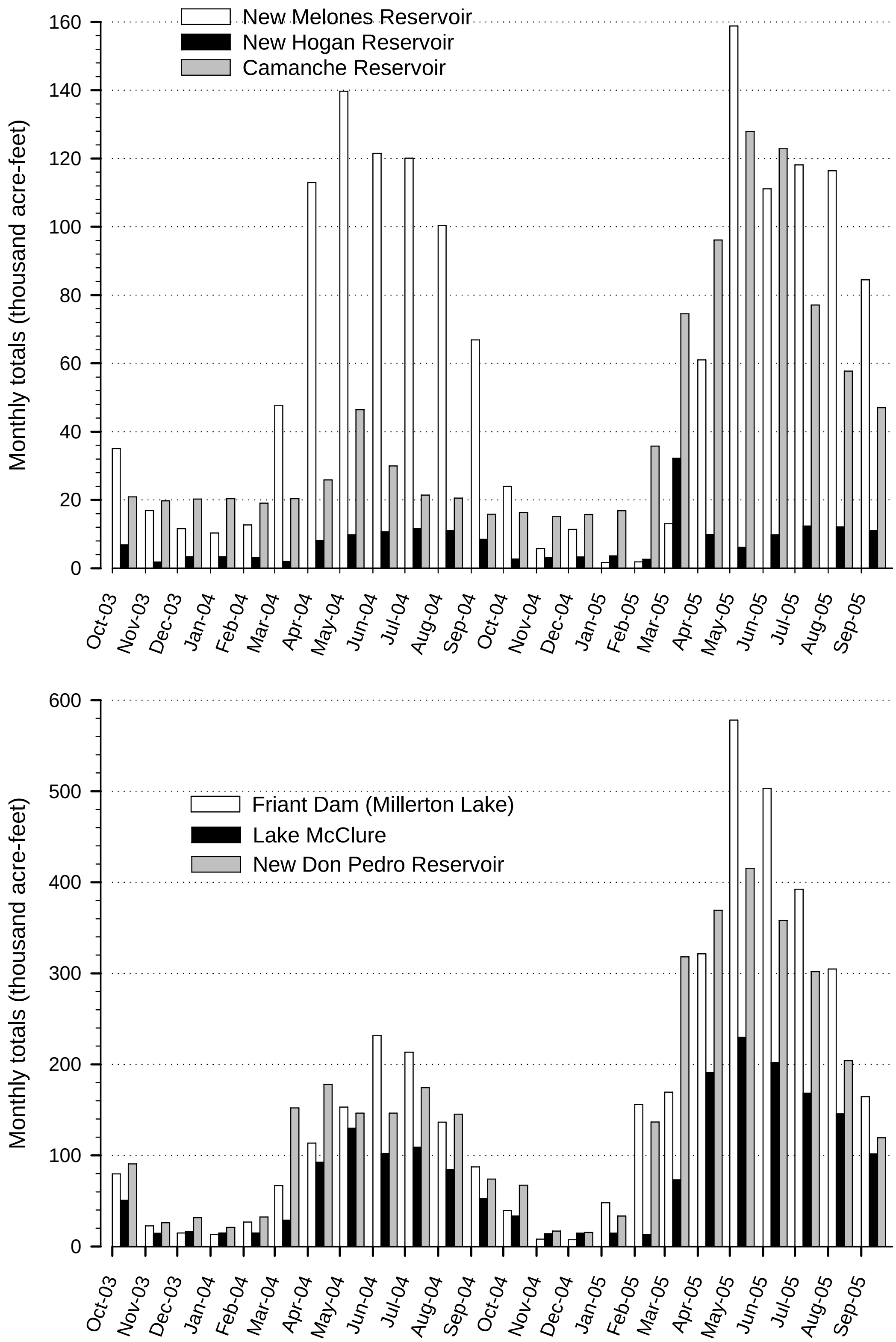

Figure 2-5 Delta total outflow and major river inflows, 2004 and 2005 water years

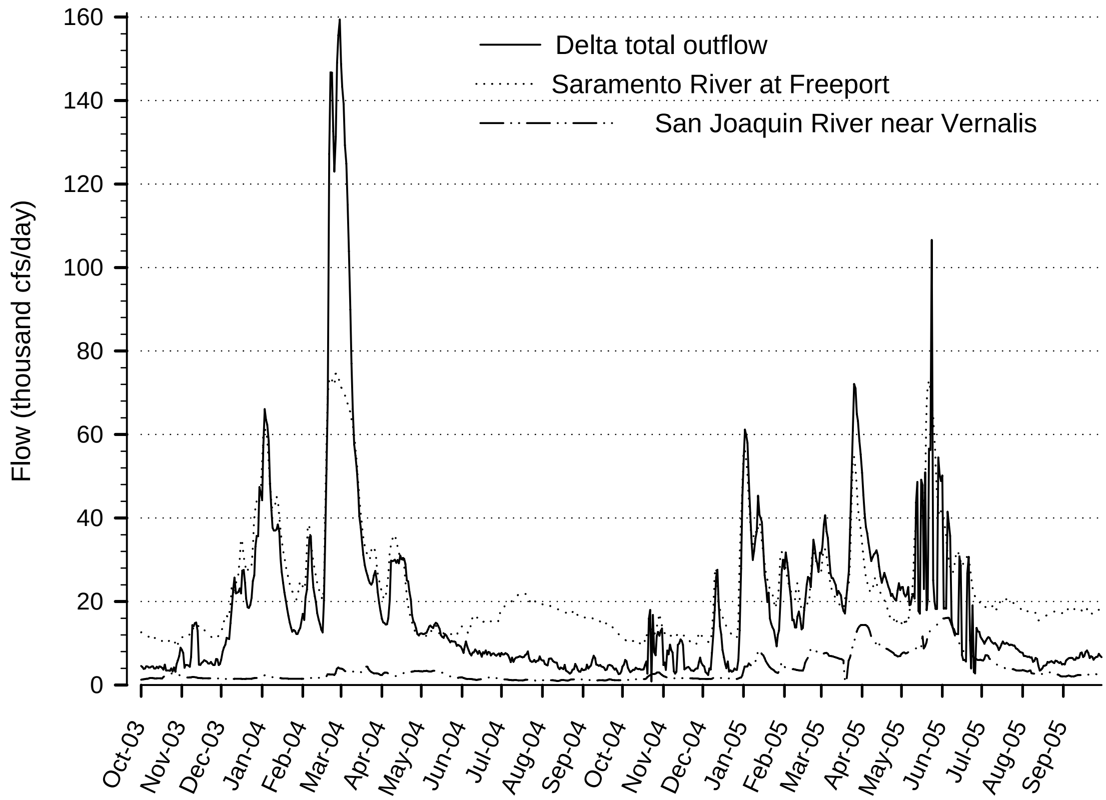

Table 2-1 Summary of daily precipitation (inches) at six weather stations

Station	Reporting days	Days rained	Range[a]	Mean[a]	Median[a]	Days of varying intensity			
						≥ 0.1	≥ 0.5	≥ 1	≥ 2
Sacramento Valley									
Redding Fire Station	731	198	0.04 – 4.76	0.49	0.24	147	63	26	10
Durham	731	173	0.01 – 1.93	0.27	0.14	103	34	5	0
Sacramento State University	731	145	0.01 – 1.93	0.26	0.13	83	30	5	0
San Joaquin Valley									
Stockton Fire Station	731	113	0.01 - 1.48	0.28	0.20	80	19	4	0
Brentwood	731	171	0.01 – 1.56	0.18	0.07	77	15	7	0
Madera	731	105	0.01 – 0.89	0.16	0.06	45	8	0	0

a. Calculated with data from days with rain.

Table 2-2 Summary of monthly precipitation (inches) at six weather stations

			Monthly precipitation			Cumulated precipitation in water year [b]	
Station	Reporting months	Months rained	Range[a]	Mean[a]	Median[a]	2004	2005
Sacramento Valley							
Redding Fire Station	24	19	0.08 – 15.24	5.14	3.84	46.20	51.44
Durham	24	18	0.57 – 7.13	2.60	2.20	21.10	25.74
Sacramento State University	24	19	0.08 – 4.85	2.00	1.93	15.47	22.56
San Joaquin Valley							
Stockton Fire Station	24	17	0.01 – 3.88	1.87	2.16	12.64	19.17
Brentwood	24	22	0.01 – 3.86	1.37	0.97	12.12	18.08
Madera	24	18	0.01 – 2.66	0.93	0.76	6.77	9.96

a. Calculated with data from months with rain.

b. Water year runs from October 1 to September 30; for example, the 2005 water year runs from October 2004 through September 2005.

Table 2-3 Hydrologic index classification based on measured unimpaired runoff at selected rivers

Water year	Sacramento Valley	San Joaquin Valley
Previous summary period		
2001	Dry	Dry
2002	Dry	Dry
2003	Above Normal	Below Normal
Current Summary Period		
2004	Below Normal	Dry
2005	Above Normal	Wet

Table 2-4 Delta Cross Channel operations

Open	Closed
06/12/03 to 12/01/03	12/01/03 to 05/28/04
05/28/04 to 06/01/04	06/01/04 to 06/03/04
06/03/04 to 12/05/04	12/05/04 to 12/28/04
12/28/04 to 12/29/04	12/29/04 to 06/25/05
06/25/05 to 11/16/05	–

Chapter 3 Organic Carbon

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Table

Chapter 3 Organic Carbon

This chapter summarizes data for organic carbon collected at 10 stations in the Sacramento-San Joaquin Delta (Delta) region from October 1, 2003, to September 30, 2005. For the Mallard Island and Contra Costa Pumping Plant stations, sampling frequency was monthly. For the rest of the stations, weekly samples were collected from November 2003 to April 2004 in addition to the monthly samplings. For the Banks, Hood, and Vernalis stations, weekly or biweekly samples were collected during the entire reporting period. These 3 stations have real-time monitoring equipment installed, and weekly or biweekly maintenance trips to these stations were necessary. During these maintenance trips, grab samples were collected.

Organic carbon data were acquired by 2 analytical methods of differing oxidizing power. One method, commonly referred to as the combustion method, oxidizes organic carbon with high temperature; the other method, commonly referred to as the wet oxidation method, oxidizes organic carbon with chemical oxidants. The combustion method destroys organic carbon more thoroughly than does the wet oxidation method, which destroys only the more easily oxidizable organic carbon. Previous analyses of samples using both methods suggested that total organic carbon (TOC) values measured by the combustion method were approximately 20% to 25% higher than those values measured by the wet oxidation method. Dissolved organic carbon (DOC) data by both methods were not statistically different (DWR 2003, 2005). During the current reporting period, TOC and DOC at Hood, Vernalis, and the Natomas East Main Drainage Canal (NEMDC) were determined by both the combustion and wet oxidation methods. The remainder of the stations used only the wet oxidation method. This report will only summarize TOC and DOC data by wet oxidation. Basic summary statistics including range, median, and averages are presented. Brief discussions on seasonality at individual stations and some limited spatial comparisons are made.

TOC = total organic carbon

DOC = dissolved organic carbon

DWR. 2003. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected Aug 1998 to Sep 2001. July.

DWR. 2005. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected Oct 2001 to Sep 2003. June.

NEMDC = Natomas East Main Drainage Canal

Stations North of the Delta

MWQI sampled 3 stations near the northern boundary of the Delta. These stations include the American River at the E. A. Fairbairn Water Treatment Plant (WTP), the Sacramento River at the West Sacramento WTP Intake, and NEMDC. Water quality at these stations represents inflows to the Delta from the American and Sacramento rivers and an urban drainage from a heavily populated urban watershed.

WTP = water treatment plan

American River at the E. A. Fairbairn Water Treatment Plant

Organic carbon concentrations were generally below 2 milligrams per liter (mg/L) at the WTP (Figure 3-1a). The only exceptions were at the onset of each rainy season when heavy rains created the first flush of the watersheds bringing particulate organic carbon into the American River, thus increasing carbon levels to between 2 and 3 mg/L (see Figure 3-1a).

mg/L = milligrams per liter

Figure 3-1 (a) Organic carbon at the American River and West Sacramento WTP Intake

Both TOC and DOC ranges were similar, while median and average TOC and DOC concentrations were the same (Table 3-1). This suggests that organic carbon was mostly in dissolved form. American River water is low in turbidity (see Chapter 7 Other Water Quality Constituents), thus the differences between TOC and DOC were small.

Table 3-1 Summary of organic carbon at 10 MWQI stations

Except at the beginning of the wet months, organic carbon fluctuations were small (see Figure 3-1a). Organic carbon was elevated during October and November of 2003 and between December of 2004 and February of 2005 in response to rainfall events in the watershed, but elevated organic carbon levels did not persist. Median TOC and DOC between the 2 water years did not differ statistically according to the Mann-Whitney test (p = 0.4065 and 0.2572 for TOC and DOC, respectively), despite 2004 water year being a "below normal" runoff year and 2005 WY being an "above normal" year (see Table 2-3).

WY = water year

Organic carbon concentrations during the reporting period were similar to those in the previous 5 water years. The ranges of TOC and DOC for the 1999 to 2003 water years were only slightly different from those of the current reporting period (see Table 3-1). The slightly lower TOC and DOC concentration ranges during the 1999 to 2003 water years were attributable to the wetter watershed runoff years relative to the current reporting period.

Sacramento River at the West Sacramento WTP Intake

The West Sacramento WTP Intake is about 2.5 miles upstream of the confluence of the American and the Sacramento rivers (see Figure 1-1). Water quality at this station reflects the quality of the Sacramento River before it mixes with inflows from the American River and before entering the Delta. Organic carbon concentrations were generally between 1 and 3 mg/L. During the onset of rainfall events (see Figure 2-2) in the watersheds in January of 2004 and 2005, organic carbon concentrations increased to above 4 mg/L (Figure 3-1b). The median levels of TOC and DOC for the reporting period were 2.3 and 2.2 mg/L, respectively (see Table 3-1), which were not statistically different according to the Mann-Whitney test (p = 0.2306). Lack of differences in ranges and medians between TOC and DOC indicates that organic carbon was mostly in dissolved form. These median concentrations were higher than those of the previous 5 water years (see Table 3-1). The current reporting period comprises 2 relatively drier water years compared with the previous 5 water years. Neither year was a wet runoff year in the watersheds during the reporting period (see Table 2-3); whereas there were 5 consecutive wet runoff years spanning from the 1995 WY to 1999 WY in the Sacramento Valley, which kept organic carbon concentration at West Sacramento WTP Intake lower than the following 3 water years (1998 to 2000).

Figure 3-1 (b) Organic carbon at the American River and West Sacramento WTP Intake

As with the American River, TOC and DOC were higher during the wet months than during the dry months. Both TOC and DOC showed less fluctuation during the dry months of the 2 water years (see Figure 3-1b). Although 2005 WY was a wetter year than 2004 WY in the watershed, median TOC and DOC were not significantly different according to the Mann-Whitney test (p = 0.6749 and 0.6951 for TOC and DOC, respectively).

Natomas East Main Drainage Canal

NEMDC at El Camino Avenue in north Sacramento is an urban drainage canal that discharges water to the Sacramento River. It collects drainage waters from one of the rapidly urbanizing and highly populated watersheds in the Sacramento Valley. NEMDC has been the subject for the past 4 years of a Municipal Water Quality Investigations (MWQI) special study that

MWQI = Municipal Water Quality Investigations monitors loads, seasonality of organic carbon, coliform bateria, and other constituents of concern.

Among the 3 MWQI stations north of the Delta, organic carbon concentrations at NEMDC were 2 to 4 times greater than those at the American River and Sacramento River at West Sacramento WTP Intake and higher than at any other MWQI station (Table 3-1). Carbon concentrations were generally much higher during the wet months than during the dry months (Figure 3-2a). Organic carbon could spike as high as 15 to 20 mg/L after initial heavy rainfall events in the watershed (see Figure 3-2a). The high organic carbon concentrations in both November 2003 and October 2004 followed the first significant rainfall events after long dry periods, and the runoff was the first flush of the watershed (see Figure 2-2). During the dry months, organic carbon varied around 5 mg/L.

Figure 3-2 (a) NEMDC organic carbon and northern Delta inflows

Median TOC and DOC were the same at 5.8 mg/L, suggesting that organic carbon was primarily in the dissolved form. These median TOC and DOC values were slightly higher than those during the previous five water years (see Table 3-1). It is not yet known whether the increased concentrations were the result of trends in the watershed or due to increased sampling frequency in this reporting period. A detailed special summary report will examine this further.

Although organic carbon concentrations at NEMDC were much higher than those in the water of the nearby Sacramento and American rivers, NEMDC inflows were generally small relative to flows in both rivers. During the reporting period, daily flows at NEMDC ranged from 10 to 4,201 cubic feet per second; whereas, combined flows at Sacramento River at Verona and American River at Lake Natoma ranged from 10,246 to 84,340 cfs (Figure 3-2b). Median flow at NEMDC (171 cfs) was less than 1% of the combined daily median flows from the Sacramento and American rivers (18,534 cfs), but TOC loads at NEMDC can be significant. About 75% of the time during the reporting period, NEMDC TOC loads were less than 5% of the loads from the Sacramento River. However, 25% of the time, NEMDC loads ranged from 10% to as high as 50% of the TOC loads from the Sacramento River (Zanoli 2006 pers comm).

cfs = cubic feet per second

Figure 3-2 (b) NEMDC organic carbon and northern Delta inflows

Zanoli, Mike (DWR). 2006 pers comm with F. Guo

Sacramento River at Hood

Water at the Hood station is a mixture of northern inflows shortly after they enter the Delta; therefore, it is one of the 2 key MWQI monitoring stations where water quality was monitored either weekly or biweekly during the reporting period. Organic carbon concentrations ranged from 1.2 to 4.9 mg/L for TOC and 1.0 to 4.3 mg/L for DOC, which were similar to those at the Sacramento River at West Sacramento River WTP Intake (see Table 3-1). Median concentrations of TOC and DOC were 1.9 and 1.7 mg/L, respectively (see Table 3-1), which were not statistically different according to the Mann-Whitney test ($p = 0.1819$). These median TOC and DOC concentrations were the same as those during the 1999 to 2003 water years (see Table 3-1).

A clear rainfall-driven seasonal pattern was observed at the Hood station. Organic carbon was elevated during the wet months and varied between 2 and 5 mg/L; whereas during the dry months, organic carbon was between 1.0 and 2.5 mg/L with only small fluctuations (Figure 3-3a). Except for the

Figure 3-3(a) Organic carbon at the Hood Station on the Sacramento River

wet-and-dry-month seasonal patterns, there was no evidence of an increase in organic carbon with time over the period from 1998 to 2005 (Figure 3-3b). For organic carbon data affected by precipitation, the median is a good indicator of baseline water quality conditions. Approximately half of each water year was affected by rain, and corresponding organic carbon values were elevated. The other half of each water year was not affected by rain, and organic carbon concentrations remained stable. If the median is taken as a measure of baseline organic carbon conditions, TOC and DOC baseline levels were 1.9 and 1.7 mg/L, respectively, for the previous 5 water years (1999 WY to 2003 WY), which were the same as the current reporting period. Median TOC and DOC concentrations for the past 7 water years (1999 WY to 2005 WY), therefore, were also 1.9 and 1.7 mg/L, respectively (see Table 3-1).

Figure 3-3(b) Organic carbon at the Hood Station on the Sacramento River

San Joaquin River near Vernalis

The San Joaquin River near Vernalis station represents the point where the SJR enters the Delta from the south. Like the Hood station on the Sacramento River, water quality near Vernalis was monitored either weekly or biweekly during the reporting period. Organic carbon concentrations generally varied between 2 and 5 mg/L, but were as high as 9 to 10.5 mg/L during January 2005 (Figure 3-4a). Median concentrations of TOC and DOC were 3.8 and 3.2 mg/L, respectively (see Table 3-1), which were significantly different ($p < 0.00001$), indicating presence of considerable particulate organic carbon in the water. These median TOC and DOC concentrations were higher than those found during the 1999 to 2003 water years (see Table 3-1). Like the stations north of the Delta, this difference may be related to runoff from the contributing watersheds. Due to 4 consecutive wet runoff years (1995 to 1998) in the San Joaquin River watershed, above normal quantities of water stored in reservoirs diluted organic carbon concentrations for the 2 water years that followed (1999 and 2000). In addition, the 1999 and 2000 WYs were both above normal, which also helped keep organic carbon levels lower than during dry water years (Figure 3-4b). In contrast, the current summary period had a dry water year in 2004. Although the 2005 WY was a wet year for the San Joaquin River watershed, organic carbon concentrations during the wet months were the highest for the past 5 water years (see Figure 3-4b), thus causing the median organic carbon concentration of the current summary period to be higher than that of the previous 5 water years.

SJR = San Joaquin River

Figure 3-4 (a) Organic carbon at San Joaquin River near Vernalis

Figure 3-4 (b) Organic carbon at San Joaquin River near Vernalis

As with north Delta stations, organic carbon concentrations were higher during the wet months than during the dry months (see Figure 3-4a). However, unlike those at the north Delta stations where organic carbon fluctuations during the dry months were generally small, organic carbon at this station may be elevated during the dry months, corresponding to the growing season in the San Joaquin Valley, especially during dry runoff years. Conversely, organic carbon concentrations have been the lowest between April and May of each water year since the Vernalis Adaptive Management Plan came into effect in 2001 (see Figure 3-4a). During dry runoff water years, as soon as VAMP releases stopped, organic carbon increased (see Figure 3-4b). During the current reporting period, the 2004 WY was a dry runoff year in the watershed. DOC increased steadily from June to September while TOC fluctuated, corresponding to drainage returns during the growing season, and was at times as high as during the wet months (see

VAMP = Vernalis Adaptive Management Plan

Figure 3-4a). This pattern was also present during the other dry water years (see Figure 3-4b). The pattern was not as evident during wet and above-normal years such as 2005 WY (see Figure 3-4).

The higher organic carbon concentrations during the dry months were attributed to agricultural drainage returns to the SJR. Agricultural drainage enters the SJR from May to October growing season of each year, thus increasing organic carbon concentrations in the river (see Figure 3-4). During the dry months, the lowest organic carbon level was observed in May and October. The low organic carbon levels in the SJR from April to May were attributed to increased reservoir releases during the VAMP period from April 15 to May 15 (see Chapter 2 Watershed and Delta Hydrology). Low organic carbon levels in October were probably due to decreased agricultural drainage entering the SJR at the end of the growing season.

Channel and Diversion Stations

Old River Stations

Two stations were sampled along the Old River: one at Bacon Island (Bacon) and the other at Pumping Station 9 near Highway 4 (Station 9). These stations are approximately 9 stream miles apart. Ten agricultural return sites from 5 islands/tracts—Holland, Bacon, Orwood, Woodward, and Victoria—drain to this section of the Old River. The Woodward and North Victoria canals and Indian Slough join with this section of the river. Aquatic vegetation growth also differs between the 2 stations.

As reported in previous MWQI reports (DWR 2003, 2005), the temporal patterns of both TOC and DOC at both stations were identical. Organic carbon data collected during the current reporting period was no exception (Figure 3-5). The ranges and medians differed only slightly (see Table 3-1). At both sites, little difference was found between TOC and DOC, suggesting that organic carbon was mostly in dissolved form. Organic carbon concentrations during this reporting period were similar to those found during the previous 5 water years (see Table 3-1). Median organic carbon concentrations of the current reporting period were only slightly different from those of the previous 5 water years (see Table 3-1).

Figure 3-5 Organic carbon at two Old River Stations

Organic carbon at Old River stations comes from multiple sources, including waters from the SJR, the Sacramento River, and Delta island drainage. Seasonal patterns of organic carbon at these stations differed from those at the river stations. Most elevated TOC and DOC concentrations were observed during the wet months when most precipitation occurred. Unlike at the Vernalis station on the SJR, organic carbon concentrations were much lower during dry months than during wet months (see Figure 3-5). At the Vernalis station, median organic carbon concentrations were as high during dry months as during wet months for both water years (see Figure 3-4).

The seasonal patterns of TOC and DOC at the 2 Old River stations may be related to elevated organic carbon in inflows from the 2 major river systems and Delta island drainage. Organic carbon concentrations in waters of both the SJR and Sacramento River were elevated during wet months (see Figures 3-3 and 3-4). When inflows of high organic carbon from both river systems reached the Old River, organic carbon concentrations would be elevated. In addition, Delta island drainage pump-outs were higher during wet months than during the rest of each water year. Organic carbon levels in drainage waters were also higher during the wet months. Therefore, organic carbon at the 2 stations was higher during the wet months than during the dry months (see Figure 3-5).

Banks Pumping Plant

Samples were collected at the Banks Pumping Plant Headworks, which is the beginning of the California Aqueduct. Organic carbon concentrations at this station represent the quality of Delta water at the point of entry into the California Aqueduct. Although TOC and DOC both exhibited a wide range (see Table 3-1), high concentrations were found mostly during the wet months (Figure 3-6a), which is similar to those of the river and channel stations. Organic carbon concentrations varied between 3 and 8.5 mg/L during the wet months. During the dry months, concentrations varied around 3 mg/L with much less variation than during the wet months (see Figure 3-6a). The increase in organic carbon during the wet months was attributable to increased loads from contributing watersheds. Organic carbon in inflow waters to the Banks station increased during the wet months; moreover, freshwater flow did not dilute organic carbon in the water because the dams and reservoirs released less water during the winter. Median TOC and DOC concentrations were 3.5 and 3.3 mg/L (see Table 3-1), respectively, which were not statistically different ($p = 0.1834$). This indicates that particulate organic carbon was low in water at the Banks Pumping Plant. These median TOC and DOC concentrations were similar to those found during the previous 5 water years (see Table 3-1).

Figure 3-6 (a) Organic carbon at two Delta diversion stations

For both water years, organic carbon decreased from May to June and leveled off between July and August (see Figure 3-6a). The decrease in organic carbon during the dry months is probably due to a combination of factors including the opening of Delta Cross Channel gates, implementation of VAMP in the San Joaquin Valley, increased reservoir releases in the Sacramento and San Joaquin valleys, and absence of storm water runoff. The Delta Cross Channel gates were opened on June 3, 2004, and June 25, 2005 (see Table 2-4), allowing the Sacramento River water a shorter route to the Banks Pumping Plant. Releases from the reservoirs in both watersheds were highest from May to August (see Figures 2-3 and 2-4).

Contra Costa Pumping Plant

Because of access restrictions, samples were only collected monthly at the outlet of the Contra Costa Pumping Plant #1. This pumping plant does not operate continuously. In the past, a sample was collected only if the pump was operating on the day when the sampling run was scheduled. During the current reporting period, a sample was collected each month regardless of pumping. This means that some samples were collected from water that was sitting still in the canal. MWQI staff keep a record of pumping activities during each sample run to this site.

Organic carbon generally varied around 3.0 mg/L at this station. The highest concentrations of organic carbon occurred during the wet months and varied from 3.5 to 6.5 mg/L depending on water year (see Table 3-1). As at the Banks station, TOC and DOC concentrations were not significantly different ($p = 0.5287$), suggesting low particulate organic carbon in the water. The ranges for both TOC and DOC were similar, and median TOC and DOC concentrations were the same (see Table 3-1). The ranges and medians were similar to those found during the previous 5 water years (see Table 3-1). Seasonal patterns at the Contra Costa Pumping Plant were similar to those at Banks Pumping Plant (Figure 3-6b) and those at the Old River stations (Bacon Island and Station 9).

Figure 3-6 (b) Organic carbon at two Delta diversion stations

Mallard Island Station

Water at the Mallard Island station is a mixture from several sources, including the SJR and the Sacramento River, the San Francisco Bay, drainage from Delta islands, and numerous municipal and industrial discharges. Because of dilution by bay waters having low organic carbon concentrations, the concentrations at Mallard Island were lower than they were at Delta channel and diversion stations (see Table 3-1). Median TOC and DOC concentrations were 2.2 and 1.9 mg/L, respectively, which is about 30% to 40% less than those found at channel and diversion stations (see Table 3-1). These median organic carbon levels were similar to those found during the previous 5 water years (see Table 3-1).

As at the other stations, organic carbon concentrations were elevated during wet months with concentrations varying from 3 to 5 mg/L (Figure 3-7a). These variations were smaller than those at the river and channel stations. Because water at this station comes from multiple sources, organic carbon seasonality differed from that at channel stations. For example, as peripheral reservoir releases decreased from July to November of the relatively drier 2004 WY, organic carbon levels increased slightly at the Banks station (see Figure 3-6a); whereas, at Mallard, as reservoir releases decreased, seawater intrusion increased as indicated by electrical conductivity increases (see Figure 6-6 in Chapter 6 Salinity). In response, organic carbon levels at Mallard decreased slightly (Figure 3-7).

Figure 3-7 (a) Organic carbon at Mallard Island

Figure 3-7 (b) Organic carbon at Mallard Island

Summary

Organic carbon at 10 MWQI stations in the Delta and its tributaries differed spatially (Figure 3-8 and Table 3-1). Overall, TOC measurements were about 15% higher than those of DOC. American River had the lowest median TOC of 1.5 mg/L. Median TOC at the Sacramento River at West Sacramento WTP Intake was 2.3 mg/L. Median TOC at Sacramento River at Hood was 1.9 mg/L, which represents the composite of the 2 previous stations. In contrast, median TOC for the SJR near Vernalis was 3.8 mg/L, which was about twice that of the TOC concentration of the northern inflows. The median TOC at Mallard Island was 2.2 mg/L, which was different from the concentrations at either the Sacramento River or SJR stations, reflecting the multiple sources of water at this station. The 4 Delta channel and diversion stations—Old River at Station 9, Old River at Bacon Island, Banks Pumping Plant, and Contra Costa Pumping Plant #1—receive water from both the SJR and the Sacramento River. Despite dilutional effects of water from the Sacramento River, median TOC concentrations for these stations ranged from 3.1 to 3.4 mg/L, which were only slightly less than that of the SJR near Vernalis, suggesting considerable in-Delta sources of organic carbon, along with the influence of the SJR. Drainage from Delta islands and in-channel production are probable sources of in-Delta organic carbon. Compared with the previous 5 water years (see Table 3-1), median TOC concentrations of

Figure 3-8 Total organic carbon: Range, median (mg/L)

most stations did not change significantly. Seasonal patterns of organic carbon concentrations differed between tributary and channel stations. Seasonal patterns at the 4 Delta channel and diversion stations differed from those at the SJR and Sacramento River stations, further indicating in-Delta sources of organic carbon.

Chapter 3 Organic Carbon

Figures

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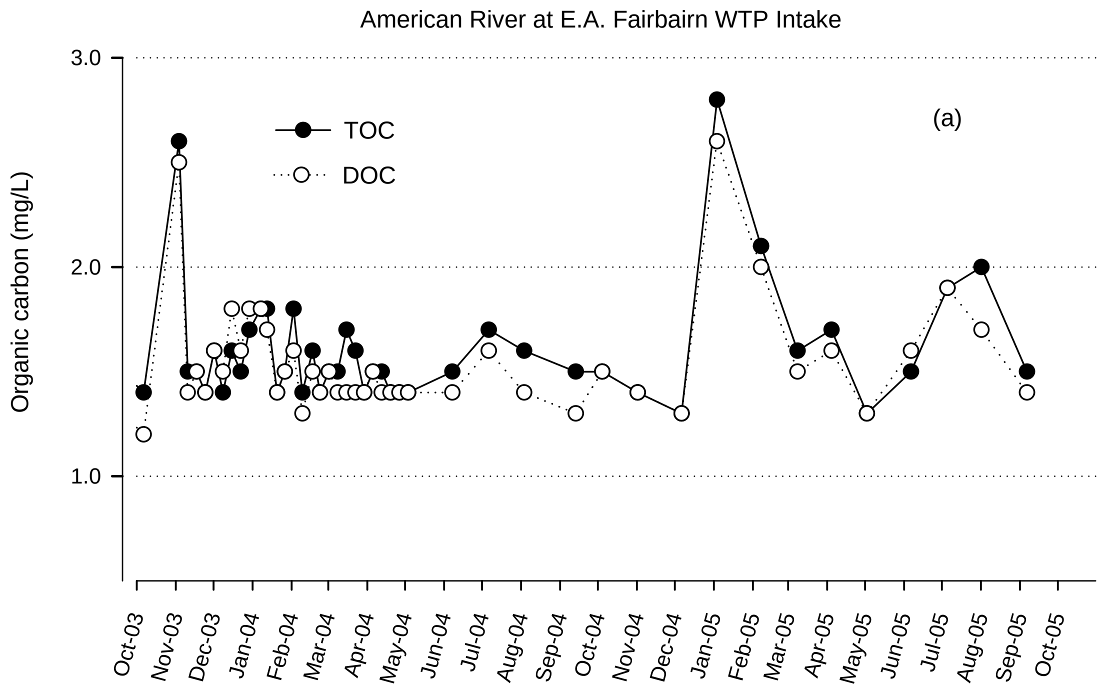
Figure 3-1 Organic carbon at the American River and West Sacramento WTP Intake



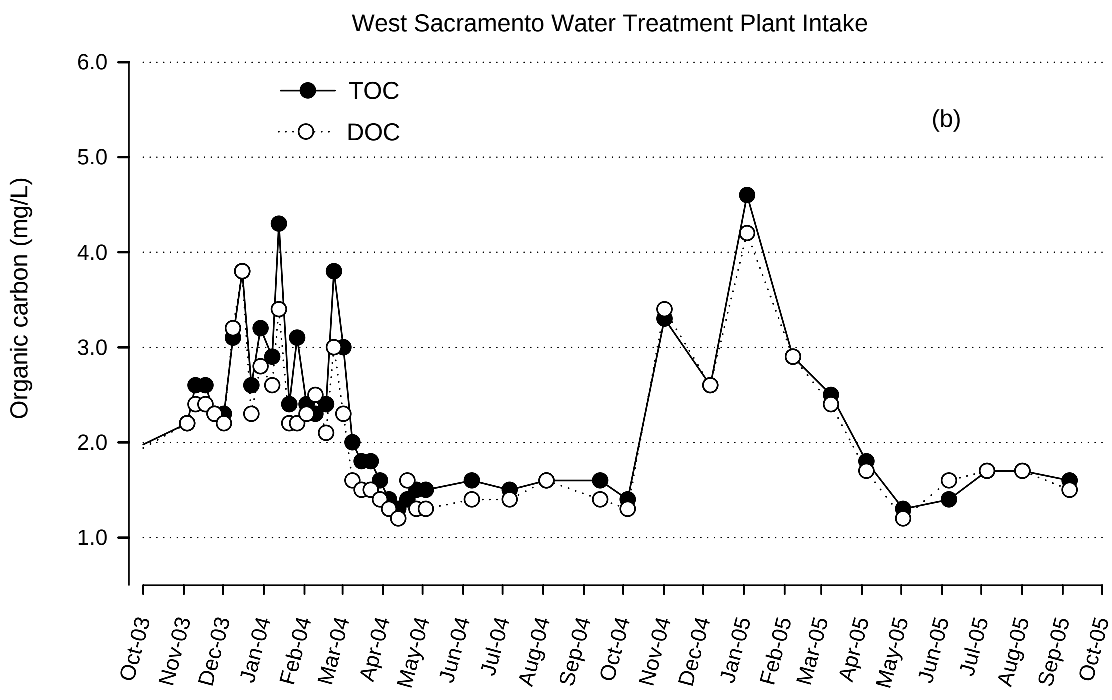


Figure 3-2 NEMDC organic carbon and northern Delta inflows

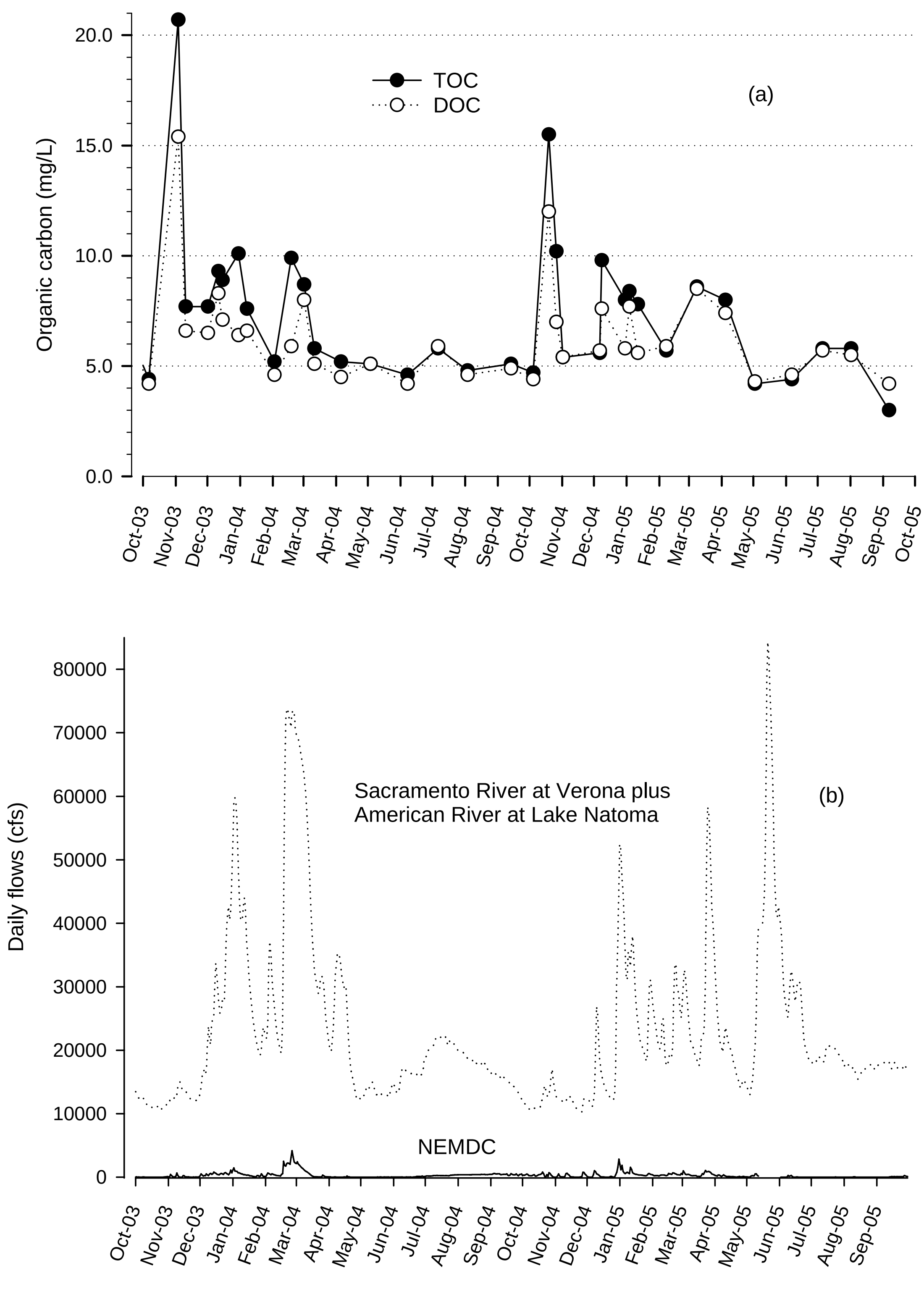


Figure 3-3 Organic carbon at the Hood Station on the Sacramento River

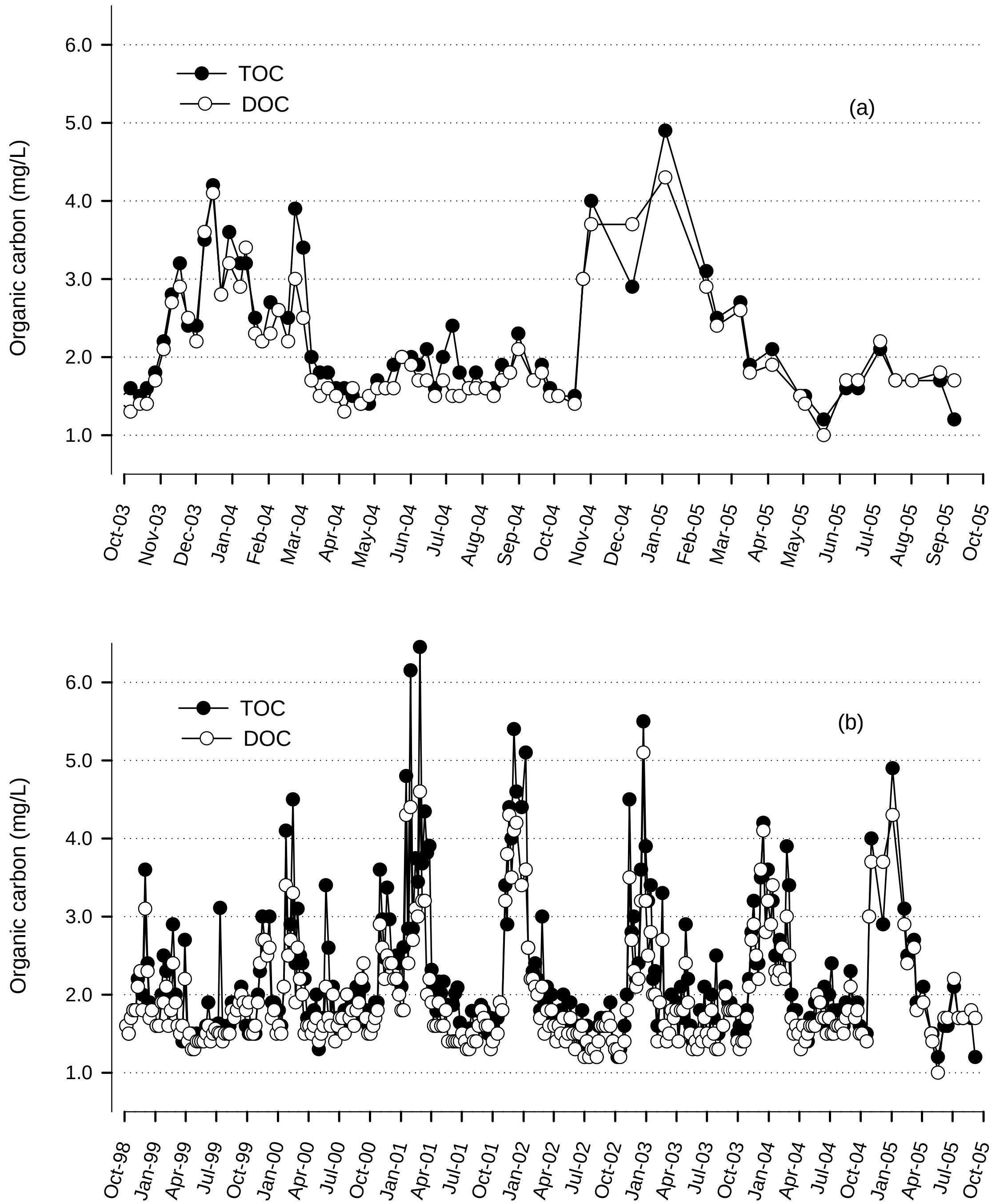
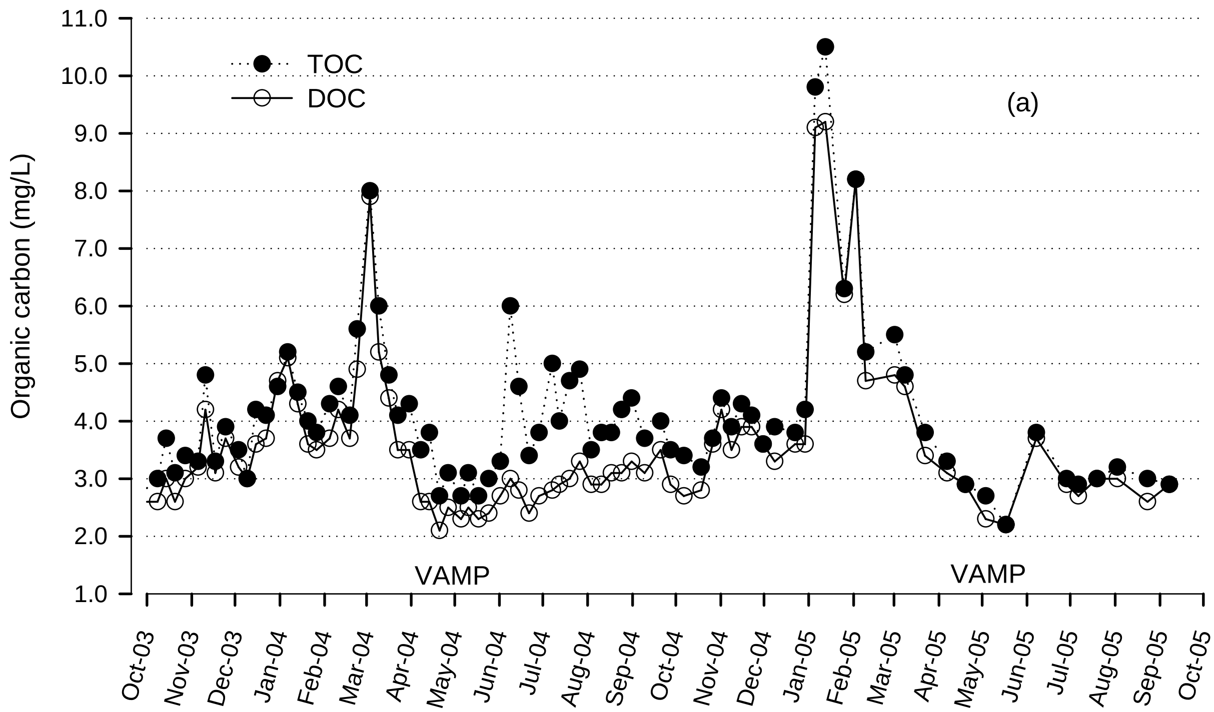


Figure 3-4 Organic carbon at San Joaquin River near Vernalis



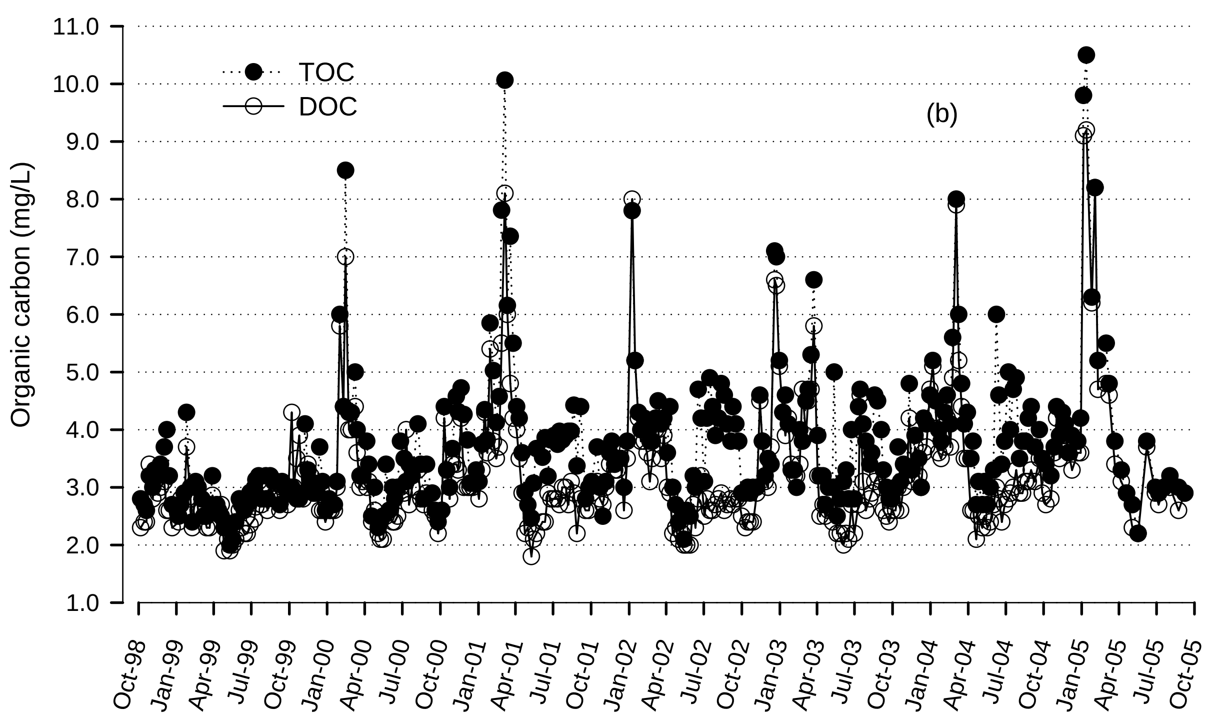
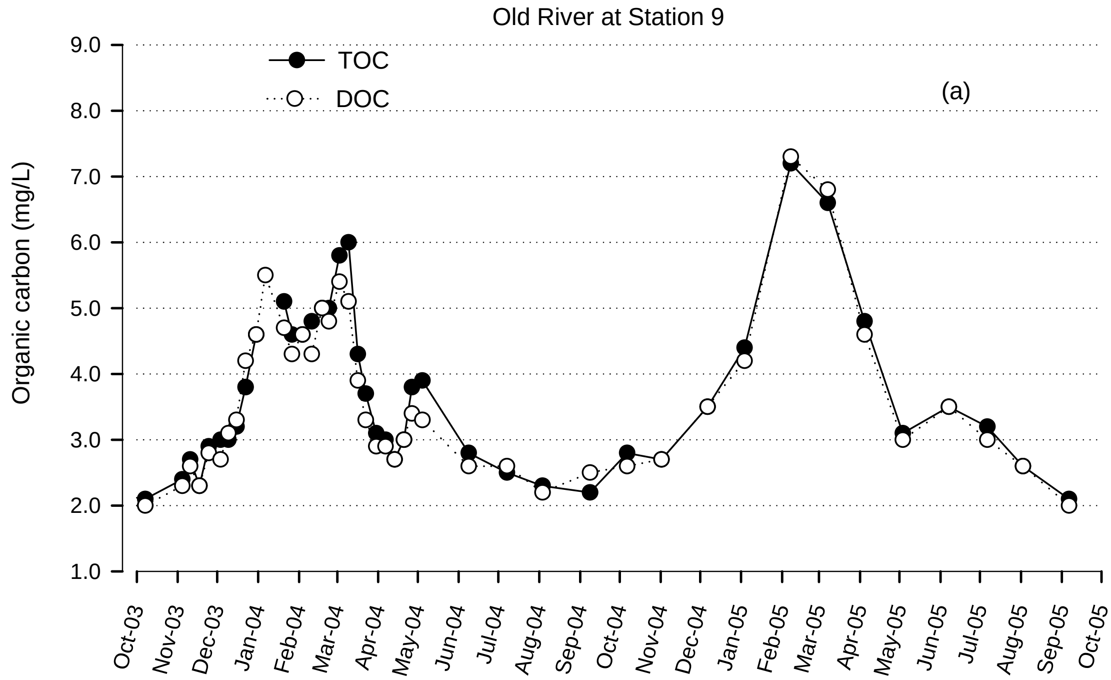


Figure 3-5 Organic carbon at two Old River Stations



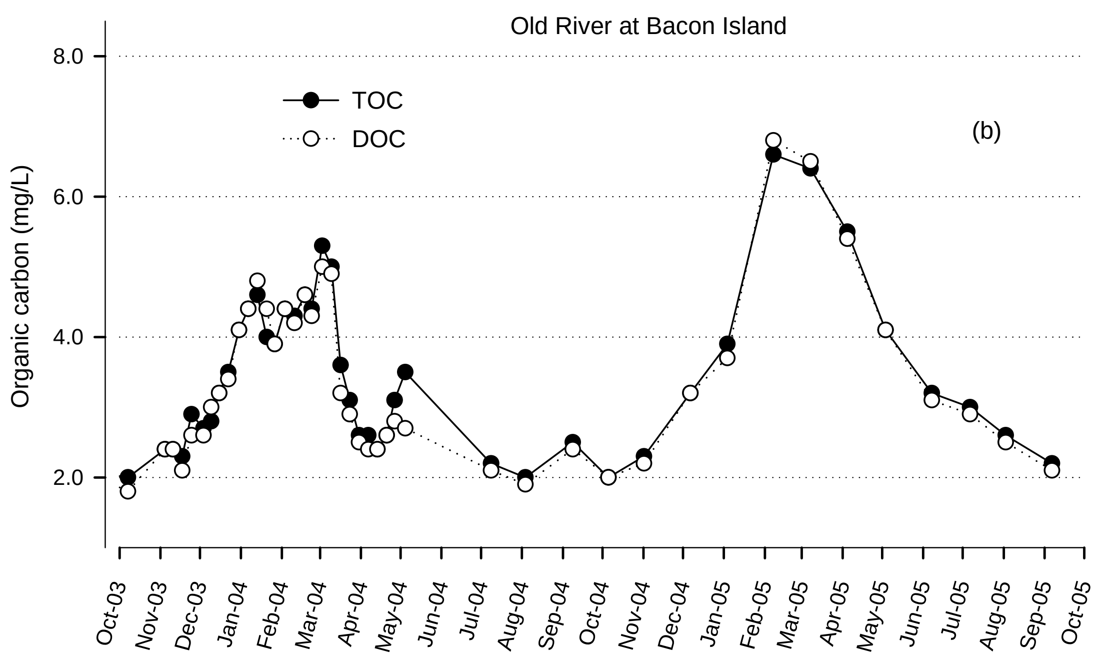


Figure 3-6 Organic carbon at two Delta diversion stations

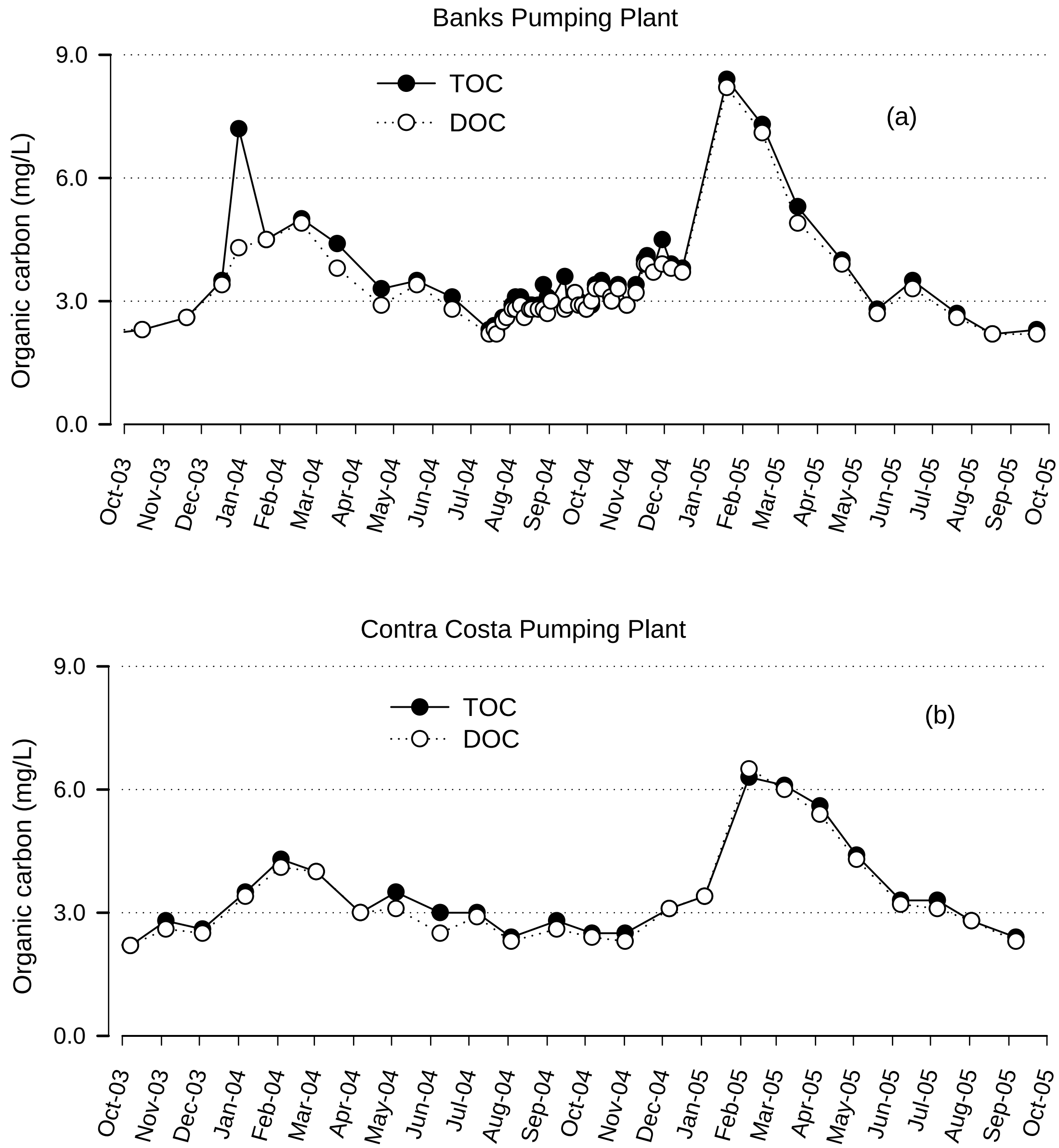


Figure 3-7 Organic carbon at Mallard Island

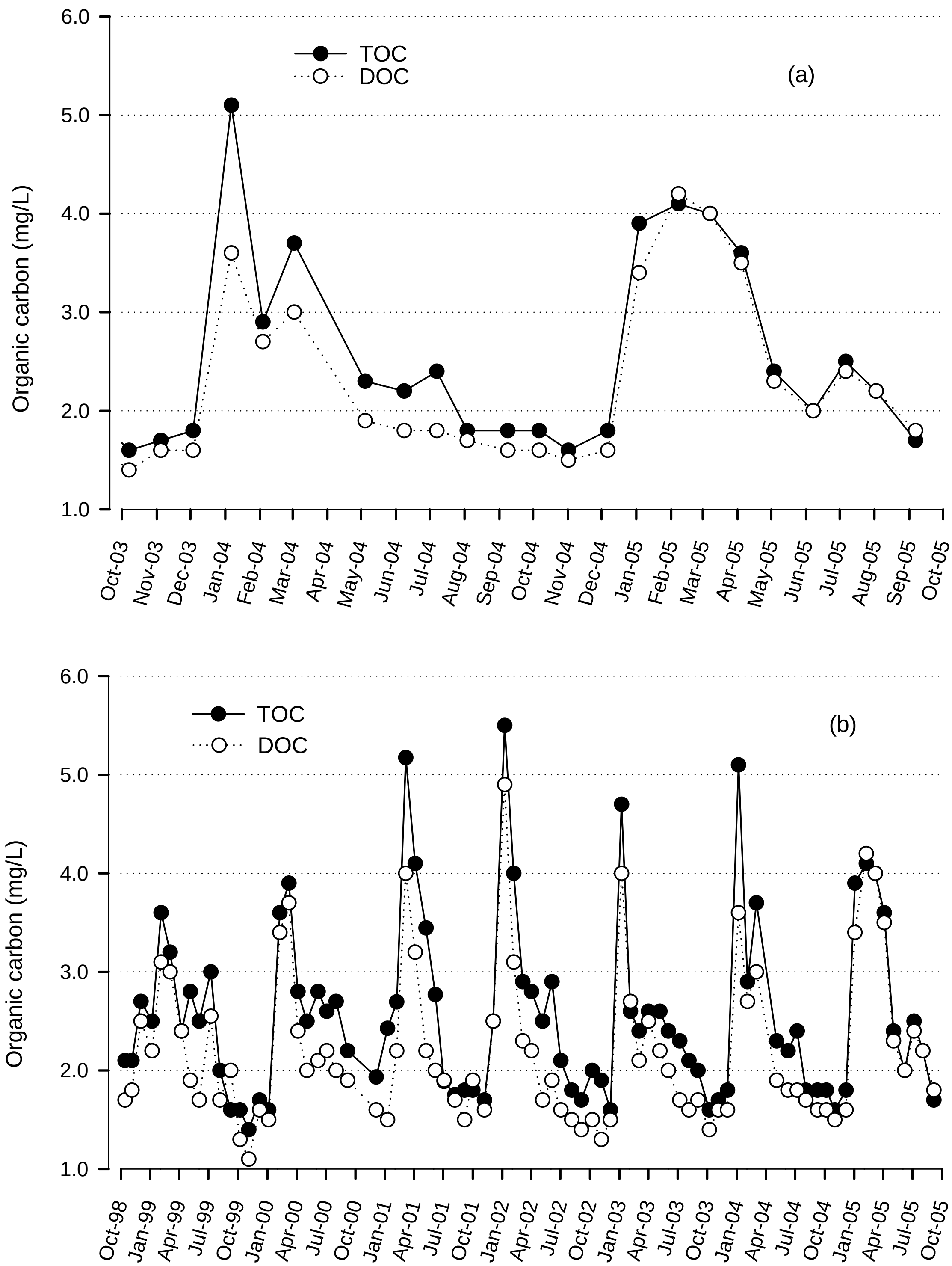


Figure 3-8 Total organic carbon: Range, median (mg/L)

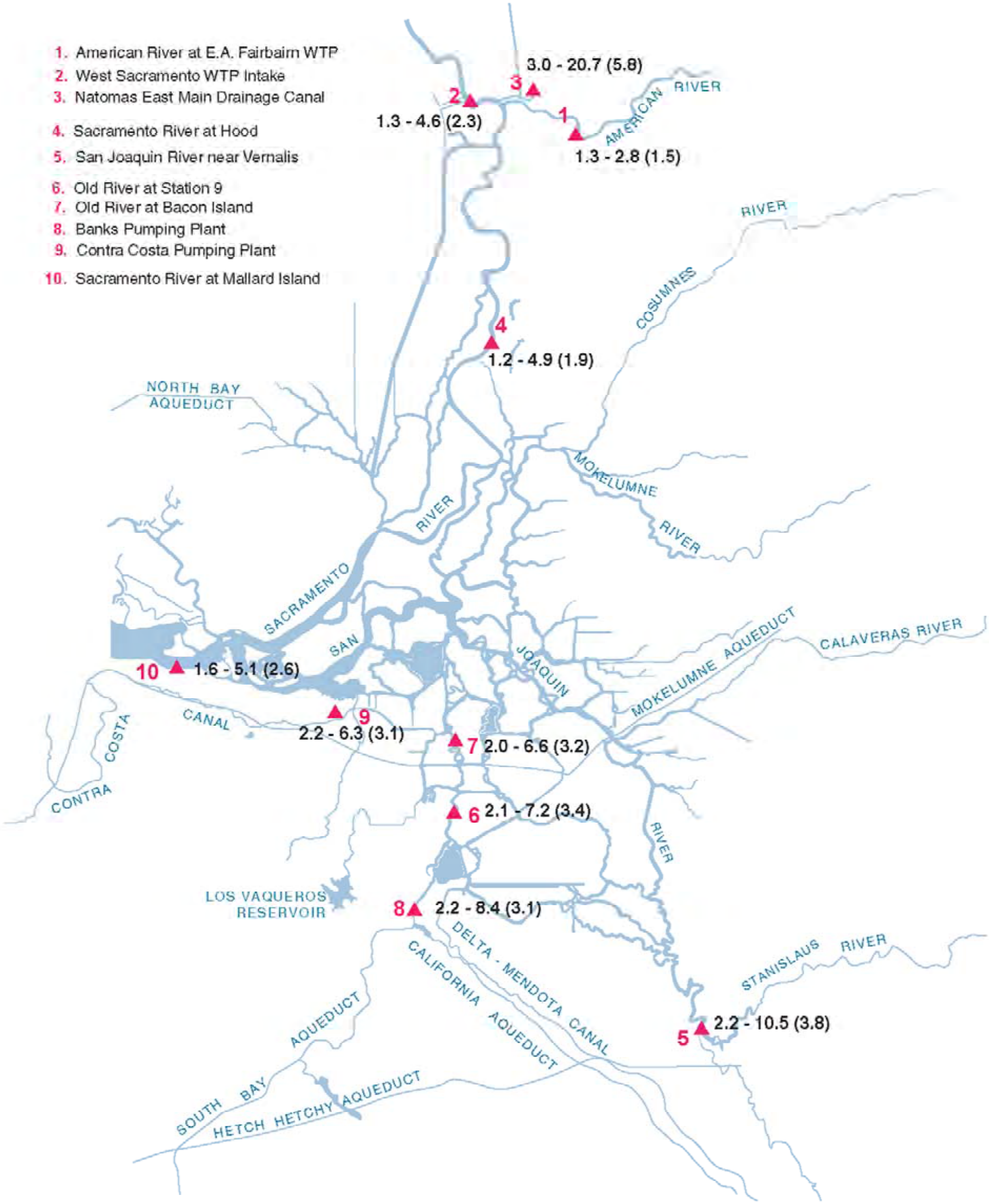


Table 3-1 Summary of organic carbon at 10 MWQI stations

Station	Constituent [a]	Oct 2003 – Sep 2005				Oct 1998 – Sep 2003 [b]	
		Sample number	Range	Average	Median	Range	Median
			----------	mg/L	----------		
Stations north of the Delta							
American River at E.A. Fairbairn WTP	TOC	44	1.3–2.8	1.6	1.5	1.1–2.8	1.5
	DOC	44	1.2–2.6	1.6	1.5	0.9–2.7	1.4
West Sacramento WTP Intake	TOC	43	1.3–4.6	2.3	2.3	1.2–5.4	1.8
	DOC	43	1.2–4.2	2.1	2.2	1.1–4.9	1.7
Natomas East Main Drainage Canal	TOC	35	3.0–20.7	7.4	5.8	3.1–36.6	5.7
	DOC	35	4.2–15.4	6.3	5.8	3.1–22.3	5.4
Sacramento River at Hood							
	TOC	72	1.2–4.9	2.2	1.9	1.2–6.5	1.9
	DOC	72	1.0–4.3	2.1	1.7	1.2–5.1	1.7
San Joaquin River near Vernalis							
	TOC	81	2.2–10.5	4.1	3.8	2.0–10.1	3.3
	DOC	81	2.1–9.2	3.6	3.2	1.8–8.1	2.8
Channel and diversion stations							
Old River at Station 9	TOC	74	2.1–7.2	3.5	3.4	1.9–8.4	3.5
	DOC	75	2.0–7.3	3.5	3.3	1.8–8.2	3.3
Old River at Bacon Island	TOC	43	2.0–6.6	3.5	3.2	1.7–7.9	3.1
	DOC	43	1.8–6.8	3.4	3.0	1.8–7.1	2.9
Banks Pumping Plant	TOC	56	2.2–8.4	3.5	3.1	1.9–8.4	3.3
	DOC	56	2.2–8.2	3.3	2.9	1.9–8.3	3.0
Contra Costa Pumping Plant	TOC	24	2.2–6.3	3.5	3.1	1.7–6.0	3.2
	DOC	24	2.2–6.5	3.3	3.1	1.5–5.4	3.4
Mallard Island							
	TOC	23	1.6–5.1	2.6	2.2	1.4–5.5	2.5
	DOC	23	1.4–4.2	2.3	1.9	1.1–4.9	2.0

a. Both TOC and DOC were determined by the wet oxidation method.

b. Banks available data were from March 2000 to September 2005.

Chapter 4 Bromide

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Chapter 4 Bromide

This chapter summarizes bromide data collected at 10 stations in the Delta region from October 1, 2003, to September 30, 2005. Sampling frequency for bromide, like organic carbon, was monthly for Mallard Island and Contra Costa Pumping Plant. For the remainder of the stations, weekly samples were collected from November 2003 to April 2004 in addition to the monthly samples. From April 2004 to September 2005, weekly or biweekly samples were collected at Banks, Hood, and Vernalis stations. These weekly or biweekly samples were collected during real-time monitoring equipment maintenance trips. This report will present basic summary statistics, including range, median, and averages for the current summary period as well as the range and median of the previous 5 water years. Brief discussions of seasonality and some limited spatial comparisons will be made for 6 seawater-affected stations.

Stations North of the Delta

MWQI = Municipal Water Quality Investigations

WTP = water treatment plant

NEMDC = Natomas East Main Drainage Canal

During the reporting period, Municipal Water Quality Investigations (MWQI) sampled one station on the American River at the E.A. Fairbairn Water Treatment Plant (WTP); one station, the West Sacramento WTP Intake, on the Sacramento River; and an urban drainage canal, Natomas East Main Drainage Canal (NEMDC).

Table 4-1 Summary of bromide at 10 MWQI stations

MDL = method detection limit

mg/L = milligram per liter

Bromide concentrations at the American River and West Sacramento WTP Intake stations were low. Of the 44 samples collected at the American River at E.A. Fairbairn WTP, bromide was never detected (Table 4-1). Water inflow to the American River mostly comes from snowmelt, which is stored in Folsom Lake. There is no known source of bromide in snowmelt. At the West Sacramento WTP Intake, 57% of the samples had bromide above the method detection limit (MDL) of 0.01 milligram per liter (mg/L). Concentrations ranged from 0.01 to 0.05 mg/L, with both an average and a median of 0.02 mg/L (see Table 4-1). The range and median concentrations during the current reporting period were similar to those found during the previous 5 water years (see Table 4-1).

Bromide concentrations at NEMDC were higher than those found at the American River at the E.A. Fairbairn WTP and the West Sacramento WTP Intake (see Table 4-1). Bromide was found below the MDL in only 9% of the 35 samples. For the positive samples, bromide concentrations ranged from 0.01 to 0.20 mg/L (see Table 4-1). Both average and median concentrations were 0.05 (see Table 4-1). These range and median concentrations were comparable to those found during the previous 5 water years (see Table 4-1). Despite bromide concentrations that were relatively higher than the 2 American River and Sacramento River stations, NEMDC water inflows were relatively small compared to the combined inflows to the American and Sacramento rivers (see Figure 3-2b). Bromide loads were low from NEMDC to the Sacramento River downstream and to the Delta.

Sacramento River at Hood

Water at the Hood station is a mixture of inflows shortly after they enter the legal Delta. Most inflows come from the American and Sacramento rivers. As shown earlier, bromide concentrations were either below MDL or varied around the MDL of 0.01 mg/L at the American River at E.A. Fairbairn WTP and the Sacramento River at West Sacramento WTP Intake. Bromide concentrations at the Sacramento River at Hood also varied near the MDL of bromide (see Table 4-1). Bromide was below the MDL in 44% of the 72 samples. For the positive samples, bromide concentrations ranged from 0.01 to 0.04 mg/L (see Table 4-1), which were comparable to those found during the previous 5 water years. Both the average and median bromide concentrations were 0.02 mg/L (see Table 4-1).

San Joaquin River near Vernalis

Of the 80 samples collected at the San Joaquin River (SJR) near Vernalis, bromide concentrations ranged from 0.02 to 0.62 mg/L, with average and median bromide concentrations of 0.26 and 0.24 mg/L, respectively (see Table 4-1). These bromide levels were similar to those found during the previous 5 water years when bromide concentrations ranged from 0.04 to 0.60 mg/L with a median of 0.25 mg/L (see Table 4-1).

SJR = San Joaquin River

Bromide concentrations were generally higher during the start of the wet months when precipitation or intentional winter flooding of agricultural fields caused surface runoff with high bromide levels from agricultural lands of the San Joaquin Valley to the SJR (Figure 4-1). December, January, and February runoff represented the first wash of accumulated salts and bromide in the soils, thus causing a surge in bromide concentrations in the SJR. Bromide concentrations were the lowest between mid-April and mid-May to mid-June (see Figure 4-1), which coincides with the Vernalis Adaptive Management Plan period (see Chapter 2 Watershed and Delta Hydrology) when SJR flows were increased by additional reservoir releases to the Merced, Stanislaus, and Tuolumne rivers. The seasonal pattern of bromide differed from that of organic carbon at the SJR near Vernalis station. Organic carbon concentrations at Vernalis were generally lower and less variable during the dry months than during the wet months (see Chapter 3 Organic Carbon); however, bromide concentrations appeared to increase with time right after the Vernalis Adaptive Management Plan period from June to October (see Figure 4-1). This period represents the growing season of the San Joaquin Valley when agricultural drainage return waters were high and river flows were low.

Figure 4-1 Bromide at San Joaquin River near Vernalis

Seasonal patterns of bromide in the SJR reflect both rainfall and agricultural practices in the watershed. The San Joaquin Valley is mostly irrigated agricultural land. Irrigation water for the area comes from the Central Valley Project's (CVP) Delta-Mendota Canal (DMC), which diverts water from the south Delta. The diverted water is a source of considerable bromide loads to the Valley (DWR 2003, 2005). When irrigation water from this source is applied, bromide concentrates on the soil surface through evapotranspiration. Following either irrigation or rainfall, runoff water transports accumulated bromide to the SJR. Soils in some areas of the valley are derived from ancient marine deposits containing high levels of bromide that can be washed into the river during wet months. In some areas, shallow groundwater also carries high levels of bromide and can move into the SJR through seepage. Furthermore, inflow water in the upstream watershed with low bromide is mostly trapped in upstream reservoirs for flood control or storage purposes during the wet months, resulting in less dilution downstream. Therefore, bromide concentrations in the lower part of the river can be high during the wet months, particularly in dry water years.

DMC = Delta-Mendota Canal

CVP = Central Valley Project

DWR. 2003. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected Aug 1998 to Sep 2001. July.

DWR. 2005. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected Oct 2001 to Sep 2003. June.

During the dry months, irrigation return waters containing elevated levels of bromide are discharged into the SJR. Thus, bromide concentrations generally increased during periods of peak irrigation (May through September) and decreased at the end of the irrigation season prior to increases during the wet months (see Figure 4-1). During the reporting period, the highest bromide concentration at Vernalis was found in early August 2004 (see Figure 4-1).

The 2004 water year was an "above normal" runoff year, whereas 2005 WY was considered a "wet" runoff year in the SJR watershed (see Table 2-3 in Chapter 2 Watershed and Delta Hydrology). As a result, bromide concentrations during the 2005 WY were relatively lower (see Figure 4-1). This was attributed to dilution from increased inflows with low bromide levels from the tributaries on the east side of the upper SJR.

WY = water year

Channel and Diversion Stations

Channel Stations

MWQI monitored bromide at 2 channel stations—Old River at Station 9 and Old River at Bacon Island. Bromide was always above the reporting limit (see Table 4-1). Median concentrations of bromide were 0.11 mg/L at Station 9 and 0.08 mg/L at the Bacon Island (see Table 4-1), which were not statistically different ($p = 0.3725$) according to the Mann-Whitney test. These median bromide concentrations were the same as those found during the previous 5 water years (see Table 4-1).

Temporal patterns were similar for both channel stations (Figure 4-2a) and were similar to organic carbon patterns. Concentrations were higher from October to January/February and declined with time from February to May or July, depending on water year type for the Sacramento and San Joaquin valleys (see Figure 4-2a). This seasonality pattern differed from that of the SJR station near Vernalis (see Figure 4-1). At both stations, bromide concentrations increased from July to September/October of both water years with peak concentrations reaching those found during the wet months (see Figure 4-2a). This dry month increase in bromide was directly related to the reduced total Delta outflows from July to October of each water year. Total Delta outflows reached the lowest from July to October of both water years (see Figure 2-5). Low Delta outflow allows the tides to bring seawater to the Delta, which increases bromide concentrations. Although the 2 water years were of different water year classifications, with 2005 WY a relatively wetter year, total Delta outflows were similar (see Figure 2-5). In addition, there was a difference in sampling frequency, with more samples taken during the 2004 WY. Therefore, differences in bromide concentrations between the 2 water years were difficult to quantify.

Figure 4-2 (a) Bromide at Delta channel and diversion stations

Diversion Stations

Samples from 2 Delta diversion points—Banks Pumping Plant and Contra Costa Pumping Plant #1—were collected during the reporting period. Although median bromide concentrations at both points of diversion were the same, at 0.11 mg/L, the range was wider at the Contra Costa Pumping Plant (see Table 4-1). Consequently, average bromide concentration at the Contra Costa Pumping Plant was higher than that at the Banks Pumping Plant (see Table 4-1). This was probably due to Contra Costa Pumping Plant's greater vulnerability to seawater influence (see Figure 1-1). Compared with the previous 5 water years, ranges were narrower and median concentrations smaller for both diversion points during the current summary period (see Table 4-1).

Seasonal patterns were similar for both diversion points (Figure 4-2b). During the wet months, bromide reached its highest value from October through January/February of each water year; during the dry months, bromide concentrations were dependent on watershed runoff year (see Figure 4-2b). The 2004 WY was relatively drier than the 2005 WY for both the Sacramento and San Joaquin valleys (see Table 2-3). In response to the dry runoff year and relatively lower river inflows to the Delta in 2004 WY, bromide concentrations at both diversion locations increased from April to September 2004. In contrast, bromide concentrations decreased with time from April to August during 2005 WY (see Figure 4-2b) as a result of increased river inflows during the relatively wetter water year. The increase in bromide concentrations from late August to October of the 2005 WY was due to reduced releases from upstream reservoirs and decreased inflows to the Delta. These seasonal patterns were different from those observed at the SJR station near Vernalis (see Figure 4-1), reflecting the influences of multiple sources at the diversion pumps.

Figure 4-2 (b) Bromide at Delta channel and diversion stations

Mallard Island

The Mallard Island station is more indicative of seawater influence than are the other stations. At this station, the water is a mixture from rivers and channels in the Delta as well as from the bay. A total of 20 monthly samples were collected from this station during the current summary period. Bromide was always above the reporting limit (see Table 4-1). Concentrations ranged from 0.01 to 18.1 mg/L, the most widely variable and highest of all 10 stations (see Table 4-1). The average and median bromide concentrations were 5.31 and 3.07 mg/L, respectively. The range of bromide concentrations of the current reporting period was similar to that found during the previous 5 water years. The median concentration of this summary period, however, is much higher than the previous 5 water years (see Table 4-1).

During the wet months, bromide concentrations were similar for both water years; during the dry months of 2005 WY, bromide concentrations were lower than those of 2004 WY. As discussed previously, 2004 WY was a relatively drier year than 2005 WY (see Table 2-3). Higher bromide concentrations at Mallard during 2004 WY were related to lower runoff in the contributing watersheds. Runoff was lower in 2004 WY than in 2005 WY for both the Sacramento and San Joaquin watersheds (Table 2-3). Reservoir releases and total Delta outflow were also lower in WY 2004 than in 2005 WY (see Figures 2-3, 2-4, and 2-5). Consequently, bromide concentrations increased from May to October 2004 (Figure 4-3) as Delta outflow decreased (see Figures 2-3, 2-4, and 2-5). In contrast, bromide concentrations remained low and relatively unchanged until August of 2005 WY (see Figure 4-3) due to relatively higher Delta outflow (see Figure 2-5). The bromide increase in August 2005 was due to reduced total Delta outflow. The reservoir releases decreased because of low water levels in most upstream reservoirs at this time of the year.

Figure 4-3 Bromide concentrations at the Mallard Island station

Relationship between Bromide and Chloride

Bromide concentrations were very low at 4 of the 10 MWQI grab sampling stations. These stations included the 3 stations north of the Delta and the Sacramento River at Hood, located inside the northern boundary of the Delta. Water at these stations came from the American and the Sacramento River watersheds, which usually contain very low levels of bromide. Although there are wastewater discharges upstream of the Hood station, their influence on bromide concentrations was minor.

Bromide levels at the other 6 stations were much higher than were observed at the northern Delta stations. A detailed discussion of seawater influence on these 6 stations has been presented in a previous data summary report. As discussed in that report (DWR 2005), the ratio of chloride to bromide measured at these locations was similar to the ratio found in seawater. (Seawater contains approximately 65 mg/L of bromide and 19,000 mg/L of chloride; the bromide/chloride ratio in seawater is, therefore, roughly 0.0034.) This finding is an indication that bromide at these locations is largely of seawater origin.

During the current summary period, a total of 125 grab samples from 6 stations were analyzed for both bromide and chloride. A near perfect linear relationship was found between bromide and chloride, which can be described by this linear regression equation:

$$\text{Bromide} = 0.0034 * \text{Chloride} - 0.023, \ [r2 = 0.9989, \ p<0.0001]$$

Among the 125 samples, most bromide values greater than 0.60 mg/L were from the Mallard Island station, which is known to be susceptible to seawater intrusion. By excluding data from Mallard Island, the relationship between bromide and chloride remained linear (Figure 4-4) and may be represented by the following equation:

Figure 4-4 The relationship between bromide and chloride at six stations

$$\text{Bromide} = 0.0033 * \text{Chloride} - 0.021, \ [r2 = 0.9391, \ p<0.0001]$$

From these 2 equations, the bromide/chloride ratio in waters of the 6 central and western Delta stations ranged from 0.0033 to 0.0034, which correspond to the ratio found in seawater. This analysis provides additional evidence to support the hypothesis that the source of bromide in the Delta is primarily seawater.

Summary

Bromide concentrations were generally higher at stations closest to seawater influence (Table 4-1 and Figure 4-5). Of the 10 stations, the Mallard Island station is the closest to the Suisun Bay and had the highest median bromide (3.07 mg/L) of all stations (see Figure 4-5). The SJR near Vernalis station had the second highest bromide concentrations with a median of 0.24 mg/L. Elevated bromide in the SJR was attributable to recycling and concentration of bromide-containing irrigation waters diverted from the Delta and returned through the SJR. Soils in some areas of the Delta and San Joaquin Valley are composed of ancient marine deposits with elevated levels of bromide that can enter the SJR in agricultural drainage. Therefore, bromide levels in the SJR and Delta channels were elevated.

Figure 4-5 Bromide: Range, median (mg/L)

Median bromide concentrations at the 2 diversion stations were both 0.11 mg/L (see Figure 4-5). The stations at the north end of the Delta are not influenced by seawater; therefore, bromide concentrations were either very low or below its reporting limit of 0.01 mg/L (see Figure 4-5).

Compared with the previous 5 water years, median bromide concentrations remained unchanged except at the Contra Costa Pumping Plant #1, where median bromide was slightly higher, and at the Mallard Island station where median bromide was lower.

Data from the current summary period offered additional evidence to support findings from MWQI's previous summary report that bromide in central and western Delta waters came primarily from seawater.

Chapter 4 Bromide

Figures

Table

Figure 4-1 Bromide at San Joaquin River near Vernalis

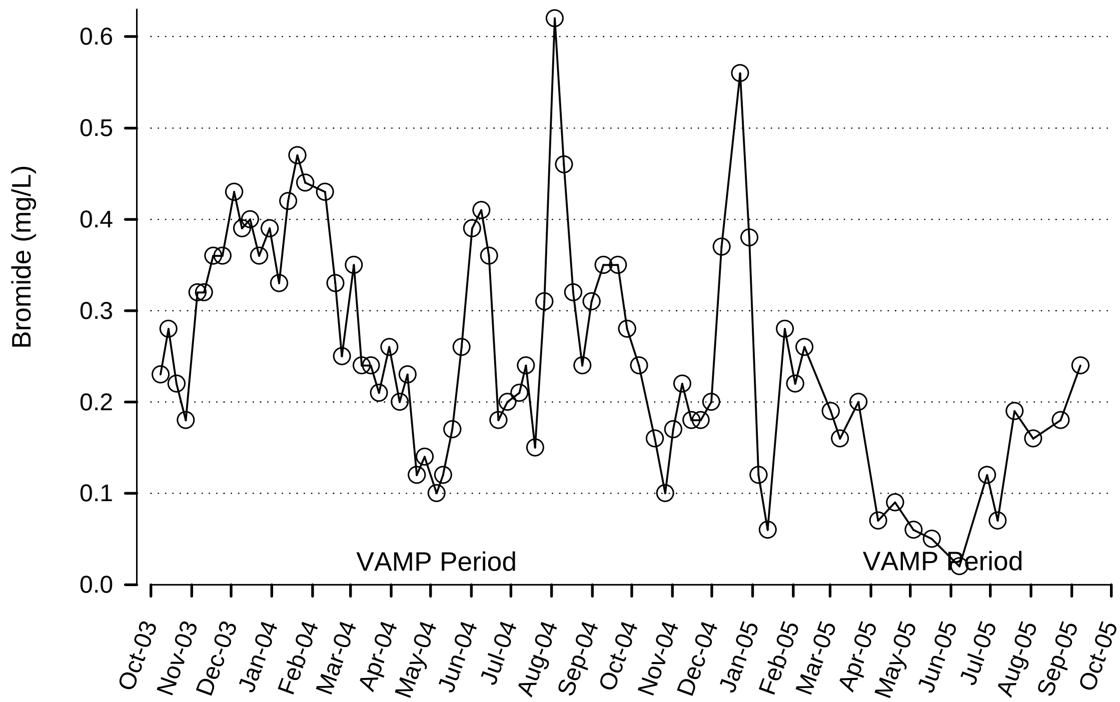

Figure 4-2 Bromide at Delta channel and diversion stations

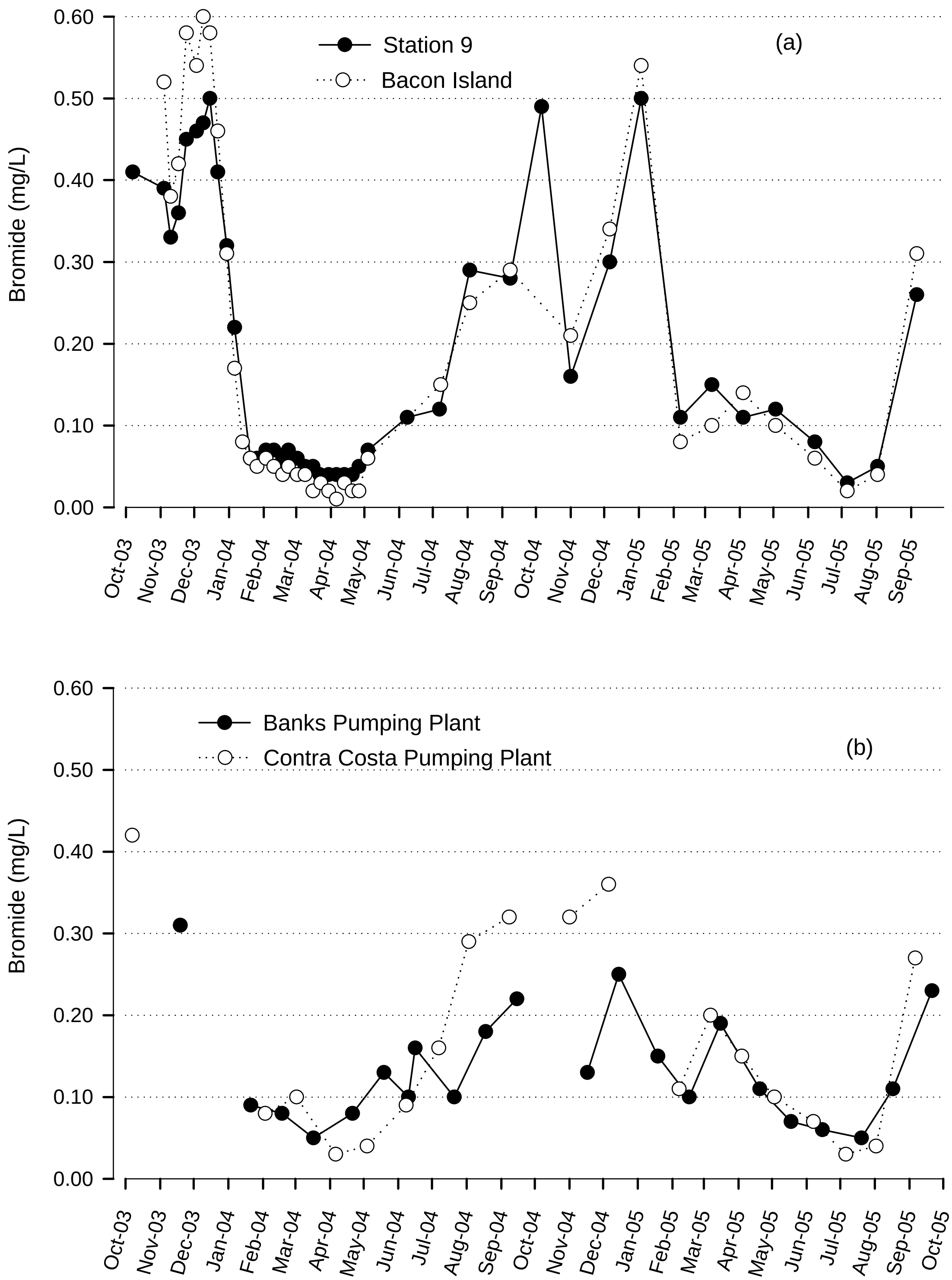

Figure 4-3 Bromide concentrations at the Mallard Island station

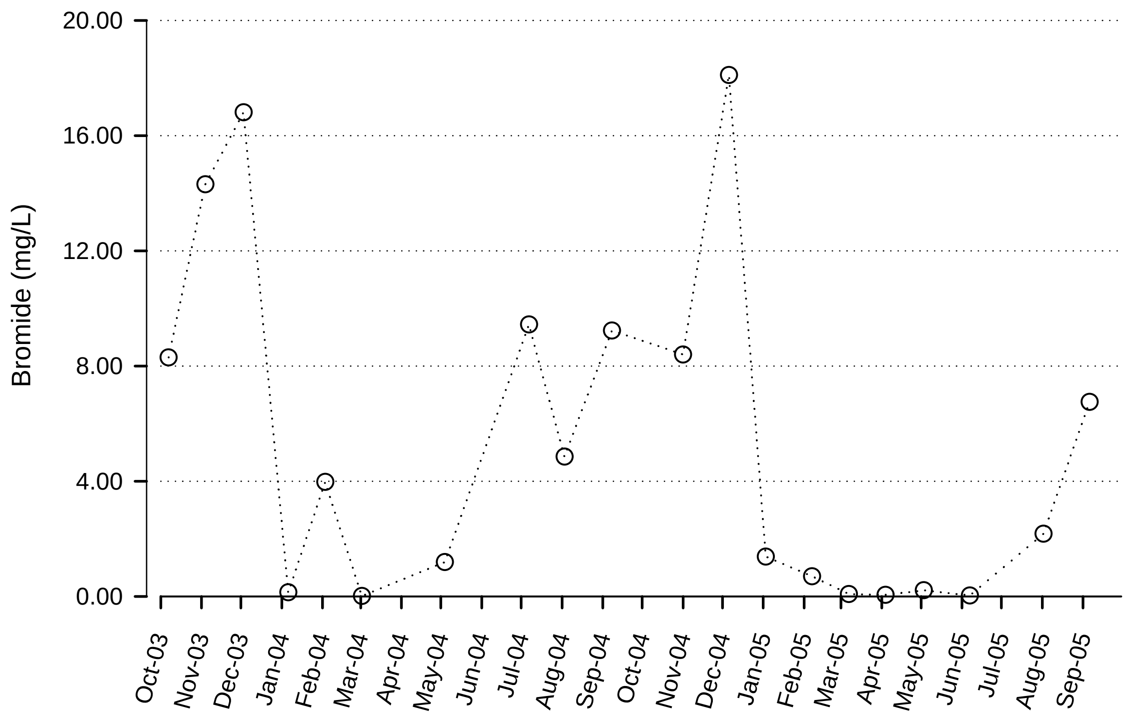

Figure 4-4 The relationship between bromide and chloride at six stations

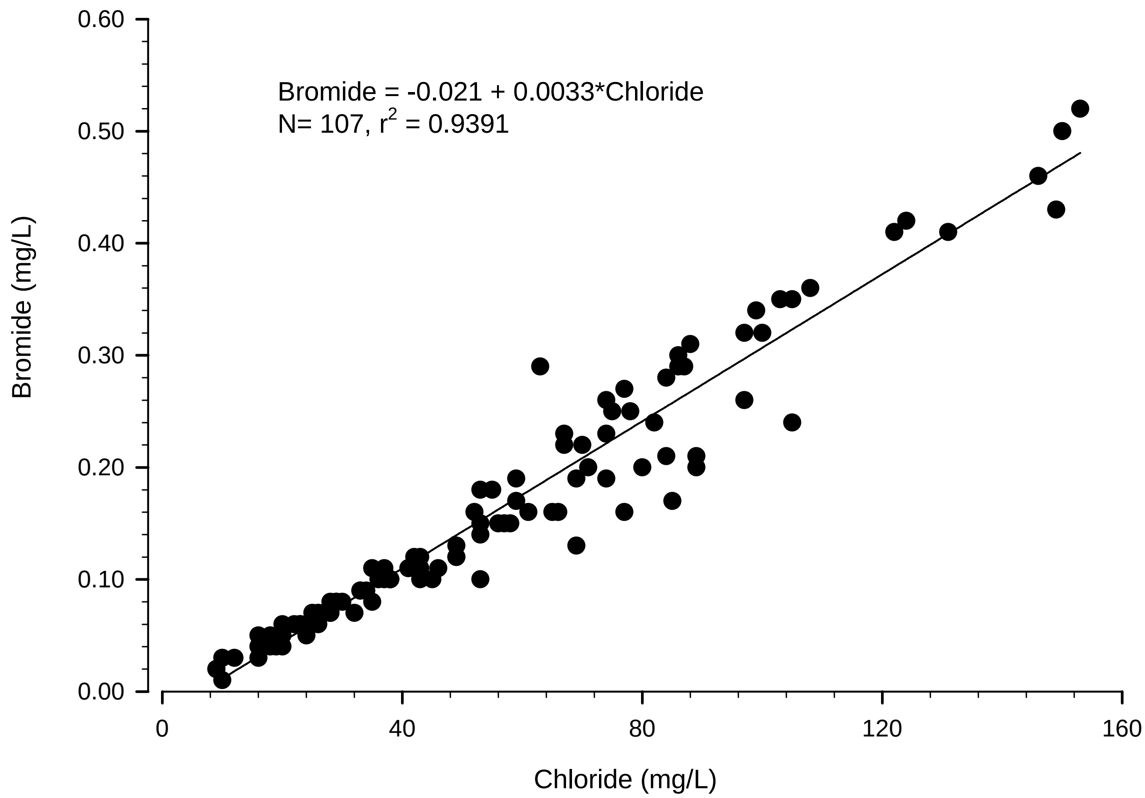

Figure 4-5 Bromide: Range, median (mg/L)

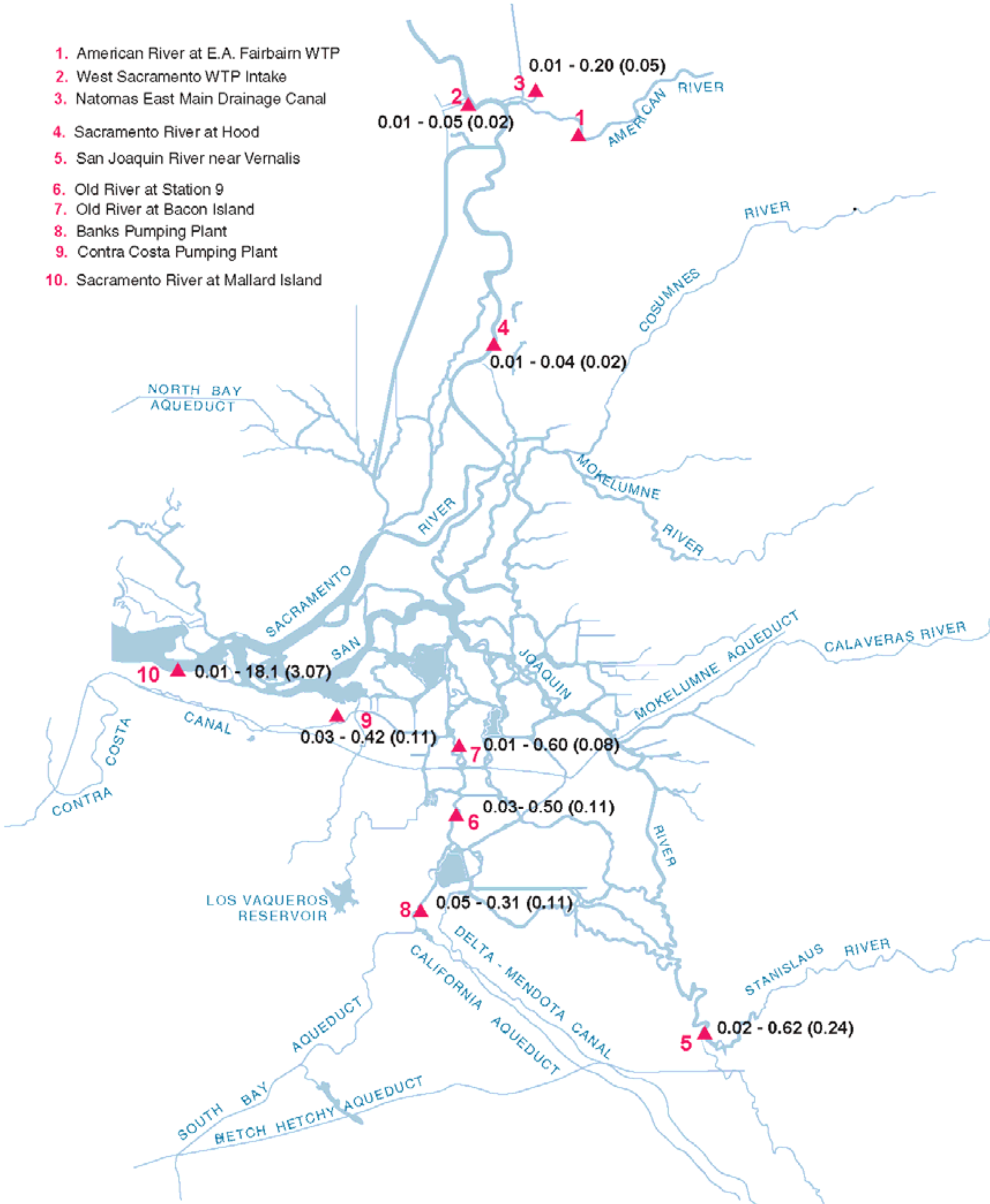

Table 4-1 Summary of bromide at 10 MWQI stations

	Oct 2003 - Sep 2005				Oct 1998 - Sep 2003		
	Detects/	Range	Average	Median	Detects/	Range	median
Station	Sample number	---------- mg/L ----------			Sample number	---------- mg/L ----------	
Stations North of the Delta							
American River at E.A. Fairbairn WTP	0/44				0/94		
West Sacramento WTP Intake	25/44	0.01-0.05	0.02	0.02	64/97	0.01-0.03	0.02
Natomas East Main Drainage Canal	32/35	0.01-0.20	0.05	0.05	87/87	0.01-0.12	0.06
Sacramento River at Hood	40/72	0.01-0.04	0.02	0.02	192/255	0.01-0.05	0.01
San Joaquin River near Vernalis	80/80	0.02-0.62	0.26	0.24	253/253	0.04-0.60	0.25
Channel and diversion stations							
Old River at Station 9	43/43	0.03-0.50	0.19	0.11	97/97	0.04-0.68	0.11
Old River at Bacon Island	41/41	0.01-0.60	0.19	0.08	139/139	0.01-0.86	0.09
Banks Pumping Plant	22/24	0.05-0.31	0.13	0.11	82/82	0.04-0.52	0.13
Contra Costa Pumping Plant	19/24	0.03-0.42	0.17	0.11	49/49	0.04-0.77	0.15
Mallard Island	20/20	0.01-18.1	5.31	3.07	56/56	0.03-20.4	2.00

Chapter 5 Nutrients

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Chapter 5 Nutrients

In the context of water quality, nutrients refer to various forms of nitrogen and phosphorus in the water. Excess nutrients lead to significant water quality problems including harmful algal blooms, hypoxia, increases in human pathogens, and deterioration in taste and odor, and aesthetic qualities. The US Environmental Protection Agency (EPA) has established primary maximum contaminant levels (MCLs) for nitrate and combined nitrate and nitrite, which are 45 mg nitrate per liter or 10 mg N/L. However, no federal or State drinking water standards have been developed for phosphorus. The EPA has been working on the development and adoption of national nutrient criteria for water quality standards since 2001, but the final standards have not yet been developed for implementation.

EPA = US Environmental Protection Agency

MCL = maximum contaminant levels

In response to the growing concern over adverse effects of nutrient-rich source waters on finished drinking water, Municipal Water Quality Investigations (MWQI) resumed regular nutrient monitoring at most stations in November 2002. Monitored nutrients include dissolved nitrate, combined nitrate and nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, and orthophosphates. Nutrient data from November 2002 through September 2003 were reported in MWQI's previous summary report (DWR 2005). This chapter summarizes data collected during the current reporting period. For discussion purposes, total inorganic nitrogen is the sum of ammonia and combined nitrate and nitrite. Total nitrogen concentrations are the sum of Kjeldahl nitrogen and nitrate and nitrite.

MWQI = Municipal Water Quality Investigations

TKN = total Kjeldahl nitrogen

DWR. 2005. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected October 2001 to September 2003. June.

Stations North of the Delta

Of all 10 stations, the lowest median concentrations of nutrients were found at the American River at E.A. Fairbairn Water Treatment Plant and at West Sacramento WTP Intake. These stations had the lowest calculated inorganic and total nitrogen medians (Table 5-1). Nutrient levels at both stations increased in the wet months after the initial flush of the watershed (Figures 5-1 and 5-2). At the West Sacramento WTP Intake, an increase in organic nitrogen (TKN) was indicated between June and October 2004 (see Figure 5-2), but inorganic nitrogen remained low during the same period. The increase in TKN was probably due to rice drainage to the Sacramento River, which begins in June of each water year and usually peaks during August and September.

WTP = water treatment plant

Table 5-1 Summary of inorganic, organic, and total nitrogen, Oct 2003 through Sep 2005

Figure 5-1 Nutrient concentrations at American River at E.A. Fairbairn WTP

Figure 5-2 Nutrient concentrations at West Sacramento WTP Intake

At both stations, concentrations of orthophosphates and total phosphorus followed seasonal patterns similar to those of nitrogen (see Figures 5-1 and 5-2). Concentrations were higher during the wet months than during the dry months. Unlike TKN, no increase in total phosphorus was observed at the West Sacramento WTP Intake between June and October 2004 (see Figure 5-2).

NEMDC =Natomas East Main Drainage Canal

Natomas East Main Drainage Canal (NEMDC) had the highest median concentrations of orthophosphates, total phosphorus, and nitrogen among all 10 MWQI stations except Vernalis, which had slightly higher median inorganic and total nitrogen (Tables 5-1 and 5-2). Unlike at the nearby river stations, concentrations of inorganic nitrogen at NEMDC was higher than TKN most of the time (Figure 5-3). Most of the total phosphorus was inorganic phosphorus (see Figure 5-3). This elevation in inorganic nutrients may be attributed to nitrogen and phosphorus fertilizers used in some areas

Table 5-2 Summary of orthophosphates and total phosphorus data at 10 MWQI stations

Figure 5-3 Nutrient concentrations at NEMDC

of the watershed. NEMDC collects water from a variety of sources including surface drainage from a highly populated watershed, small amounts of agricultural drainage, and a wastewater treatment plant. A consistent seasonality was not observed (see Figure 5-3). However, evidence of a dilutional effect on nitrogen during the wetter 2005 water year was observed (see Figure 5-3).

Sacramento River at Hood

Upstream from the Hood station are discharges from 2 wastewater treatment plants, Morrison Creek drainage from another large urban area, and an active marina. Therefore, the medians of inorganic and total nitrogen and phosphorus concentrations were more elevated at Hood than at the American River and West Sacramento WTP stations (see Tables 5-1 and 5-2). Inorganic nutrients probably came from wastewater discharges and urban runoff, causing elevation in concentrations (Figure 5-4). General seasonal trends display an increase in concentration of nutrients during the wet months of each water year and a decrease during the dry months of each water year. As atmospheric temperatures increased during the summer months and activities of aquatic organisms increased, nutrient concentrations decreased (Figure 5-4).

Figure 5-4 Nutrient concentrations at Sacramento River at Hood

San Joaquin River near Vernalis

Among all stations, the highest median inorganic and total nitrogen concentrations were found at the San Joaquin River (SJR) near Vernalis (see Table 5-1). Nutrient seasonality is complicated by applications of nitrogen and phosphorus fertilizers on agricultural lands along the SJR and its tributaries. During the wet months, nutrient levels increased with precipitation and decreased at the end of the wet months (Figure 5-5), probably due to less nutrients coming in from the watersheds and dilutional effects. In April and May when Vernalis Adaptive Management Plan was in effect, nutrient levels dropped to their lowest concentration (Figure 5-5). However, nitrogen levels began to rise in June of each year and reached the highest dry-month levels between July and October, which coincides with the growing season and more specifically with the agricultural drainage inflows to the river (see Figure 5-5). Because a considerable portion of nitrogen is bound with organic carbon, TKN was highest also at the SJR near Vernalis among all river, channel, and diversion stations; however, TKN, orthophosphates, and total phosphorus concentrations at this station were lower than those found at NEMDC.

SJR = San Joaquin River

Figure 5-5 Nutrient concentrations at SJR near Vernalis

Channel and Diversion Stations

Water at the channel and diversion stations came from multiple sources. The ranges and medians of nutrient concentrations at channel and diversion station were close to those found at Hood but less than those found at Vernalis (see Tables 5-1 and 5-2). Nitrogen concentrations were generally higher during the wet months and lower during the dry months of each water year (Figures 5-6 and 5-7). Increased algal activities in the rivers and channels of the Delta may be the cause of lower nitrogen concentration during the dry months. Higher concentrations of nutrients occurred from January to March in response to heavy rainfall; however, as precipitation continued, concentration of nutrients gradually decreased. Cyclical patterns of seasonal change were less obvious for both total phosphorus and

Figure 5-6 Nutrient concentrations at two Delta channel stations

Figure 5-7 Nutrient concentration at two Delta diversion stations

orthophosphates. Both forms of phosphorus remained relatively stable, with some increases in the wet months and some decreases during July and August of each water year (see Figures 5-6 and 5-7), presumably due to algal consumption of orthophosphates and nitrogen.

Mallard Island

Nitrogen and phosphorus concentrations at the Mallard Island station were comparable to those at the channel and diversion stations (see Tables 5-1 and 5-2). Low nutrient concentrations at Mallard Island may be attributed to several factors, including seawater influence, water diversion through pumping and biological consumption of nutrients within the Delta. Mallard Island is the most susceptible to tidal and seawater influences from the Suisun Bay. Seawater with low nitrogen concentration causes a dilutional effect on nitrogen concentrations at Mallard Island (Figure 5-8). In addition, when water passes through the biologically diverse and complex Delta, much of the nitrogen may be consumed before it reaches the Mallard Island station.

Figure 5-8 Nutrient concentrations at Mallard Island

Summary

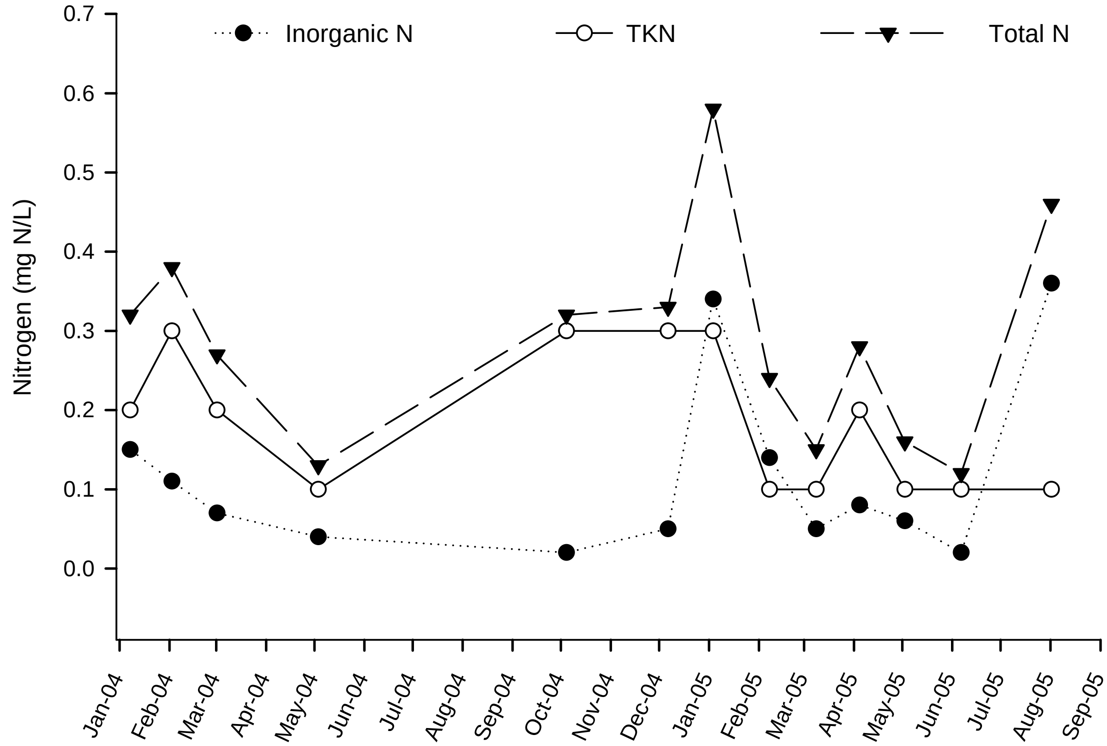
Among the 10 stations monitored for nitrogen and phosphorus during the reporting period, median inorganic and total nitrogen concentrations ranged from 0.05 to 1.50 mg/L and 0.14 to 2.30 mg/L, respectively; median orthophosphates and total phosphorus ranged from below reporting limit to 0.23 mg/L and below the reporting limit to 0.36 mg/L, respectively. The lowest nutrient concentrations were found at the American River at E.A. Fairbairn WTP, West Sacramento WTP Intake, and Contra Costa Pumping Plant. The highest nutrient concentrations were found at NEMDC and the SJR near Vernalis. Although the Hood station is near the north boundary of the Delta and receives good quality water from the American River, nutrient concentrations were much higher than at nearby stations due to urban loads and wastewater discharges upstream. Nutrient concentrations at most Delta channel and diversion stations were comparable to those at the Hood station. Nutrient concentrations at the Mallard Island station were comparable or slightly lower that those found in the Delta channel and diversion stations.

Chapter 5 Nutrients

Figures

Tables

Figure 5-1 Nutrient concentrations at American River at E.A. Fairbairn WTP



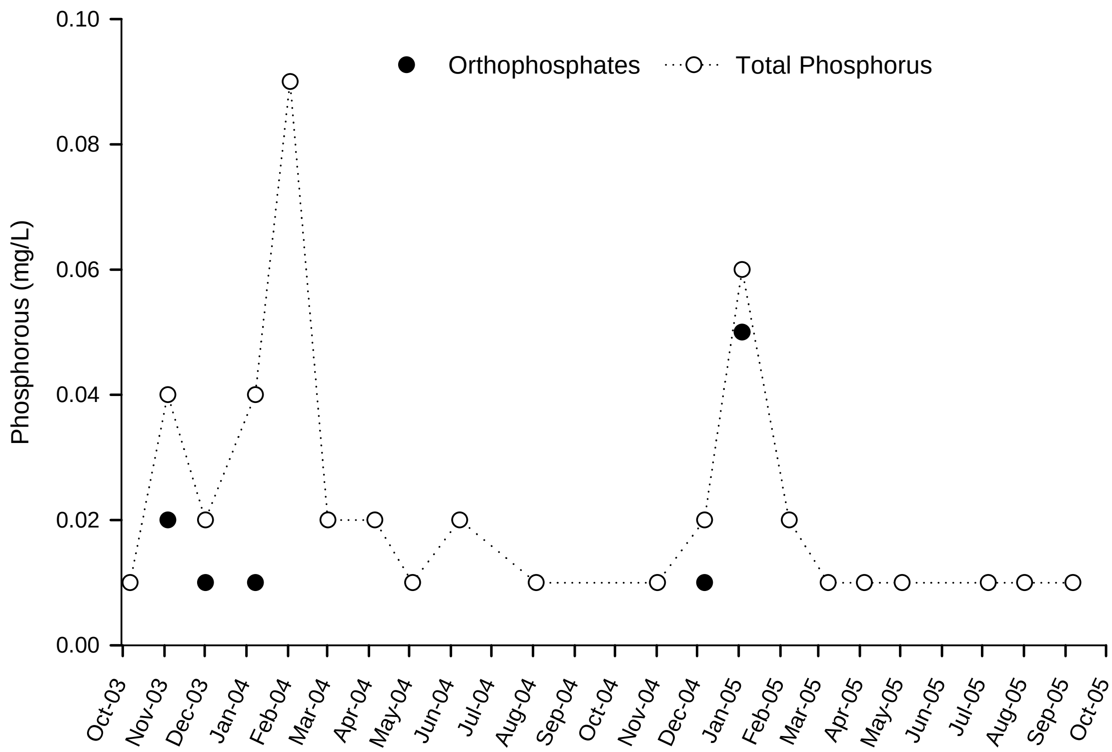


Figure 5-2 Nutrient concentrations at West Sacramento WTP Intake

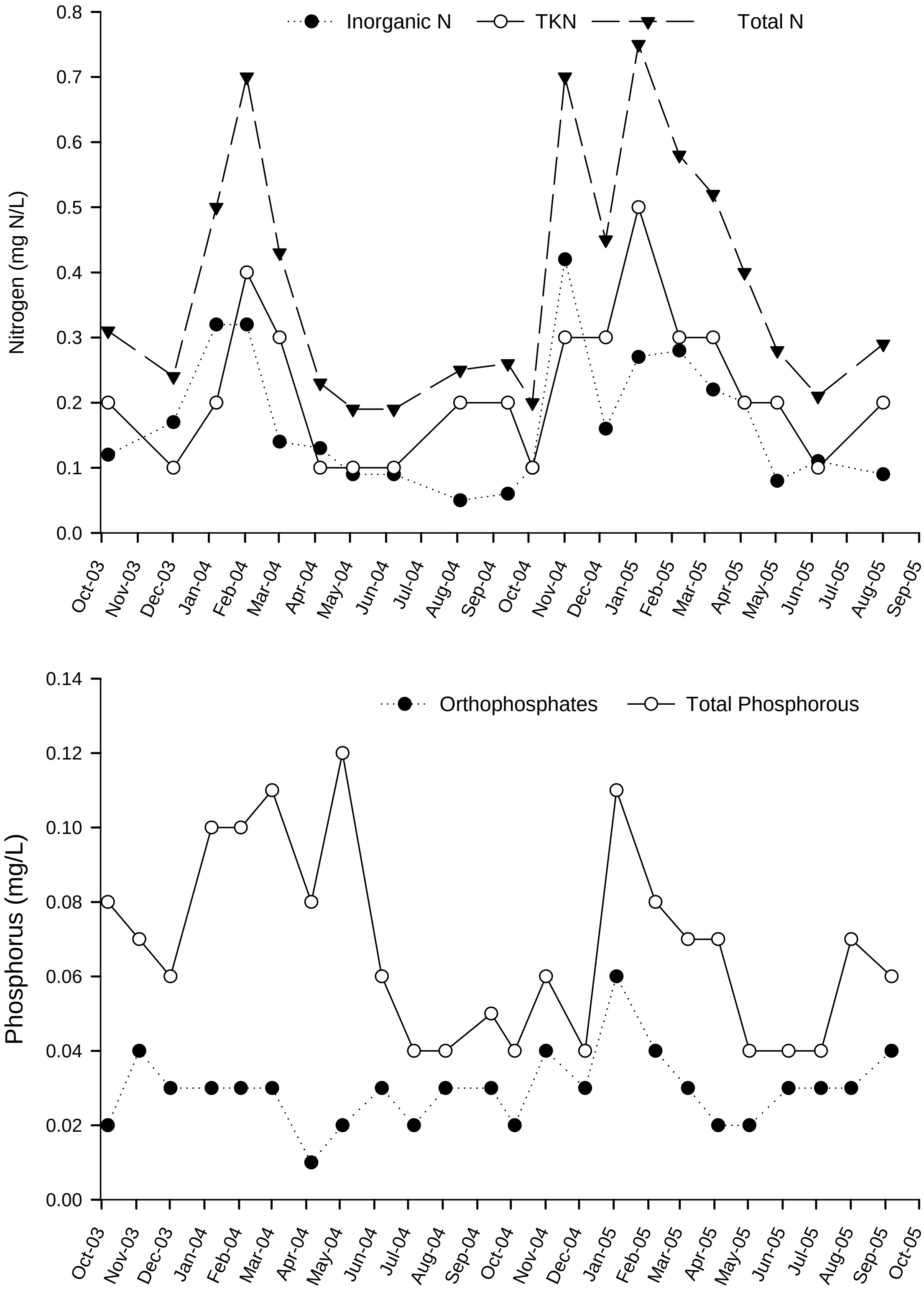
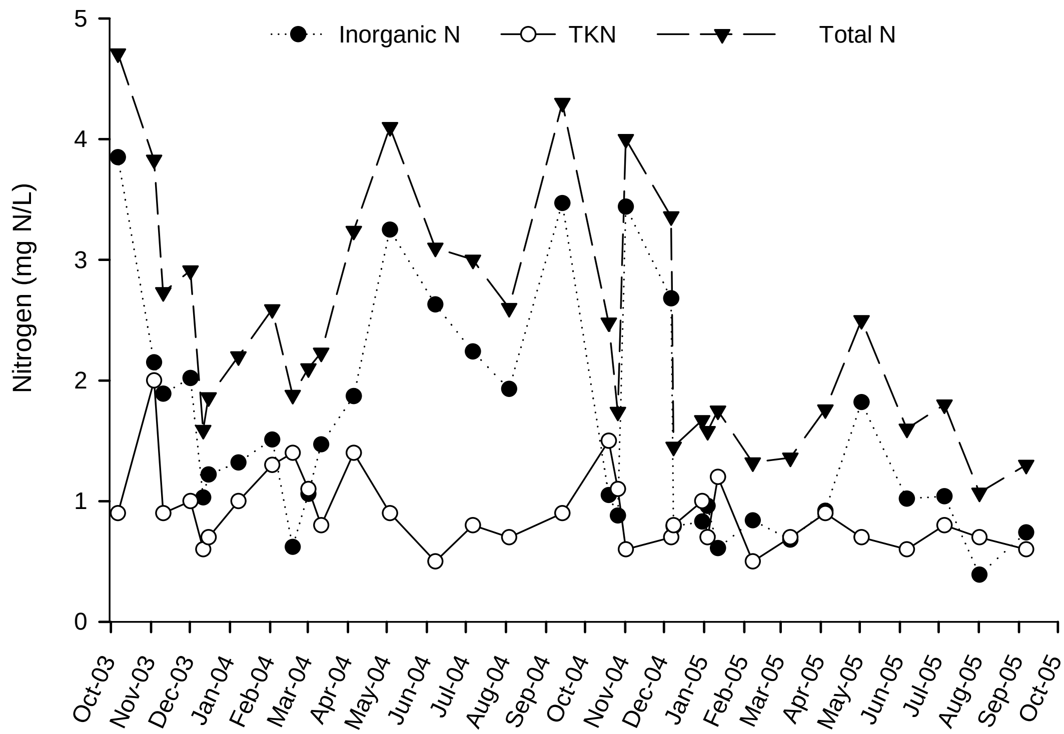


Figure 5-3 Nutrient concentrations at Natomas East Main Drainage Canal



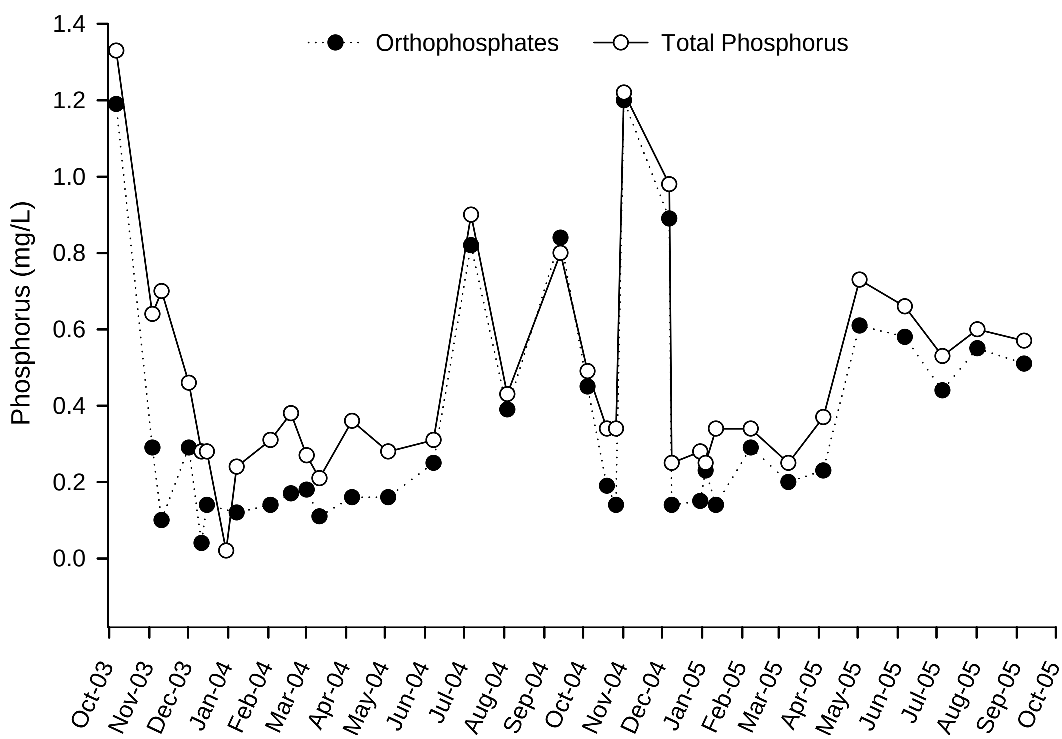


Figure 5-4 Nutrient concentrations at Sacramento River at Hood

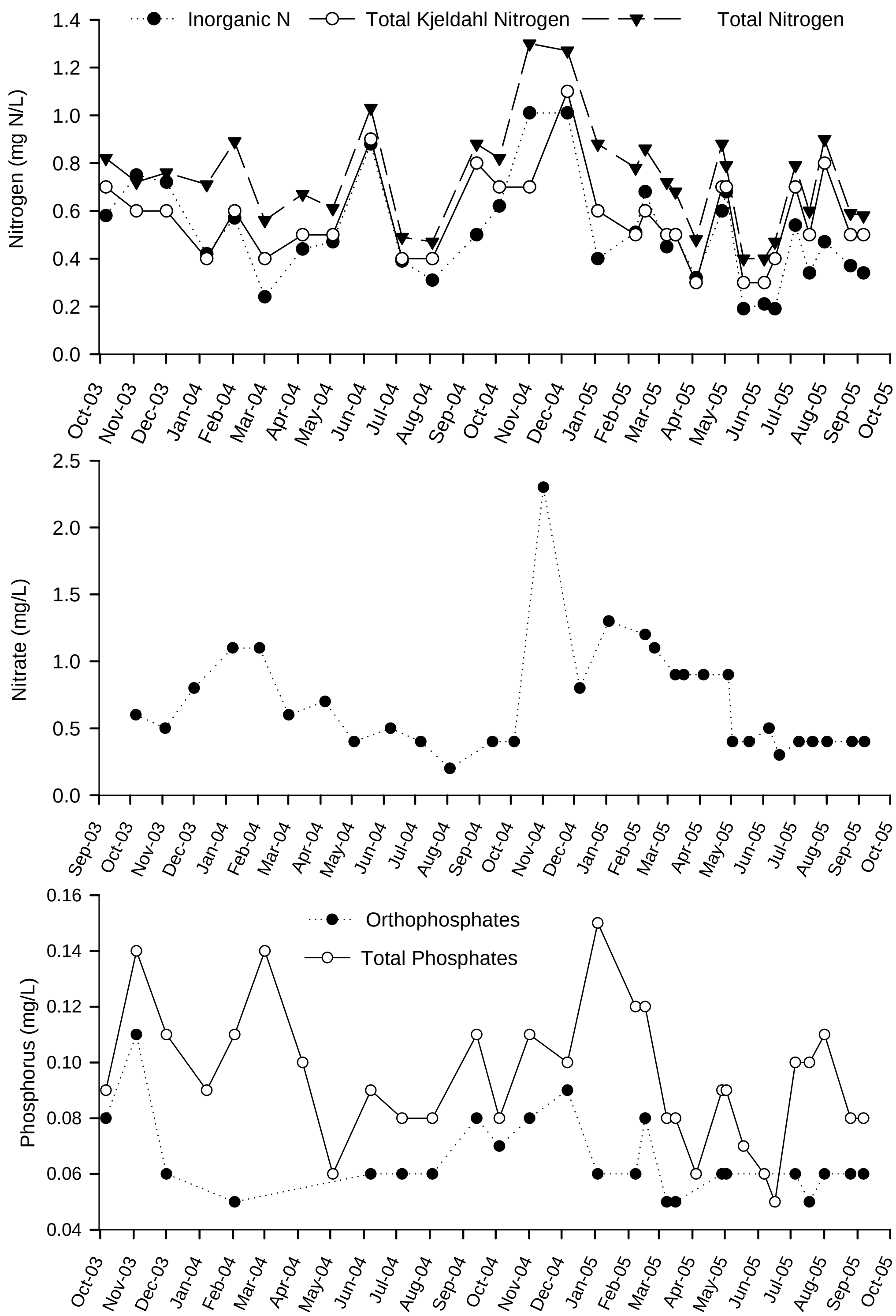
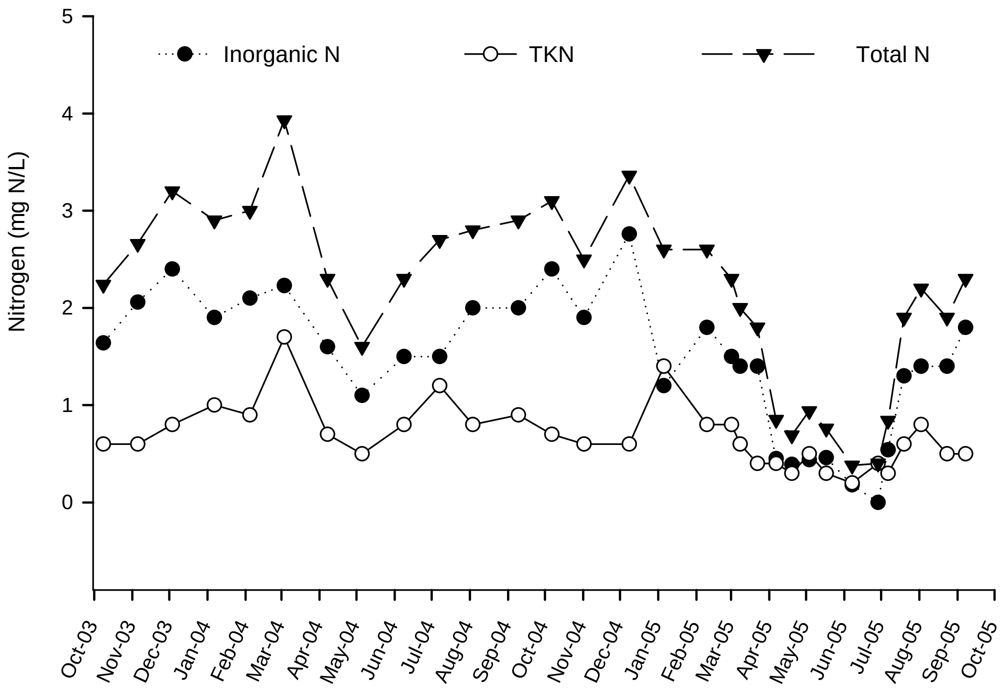


Figure 5-5 Nutrient concentrations at San Joaquin River near Vernalis



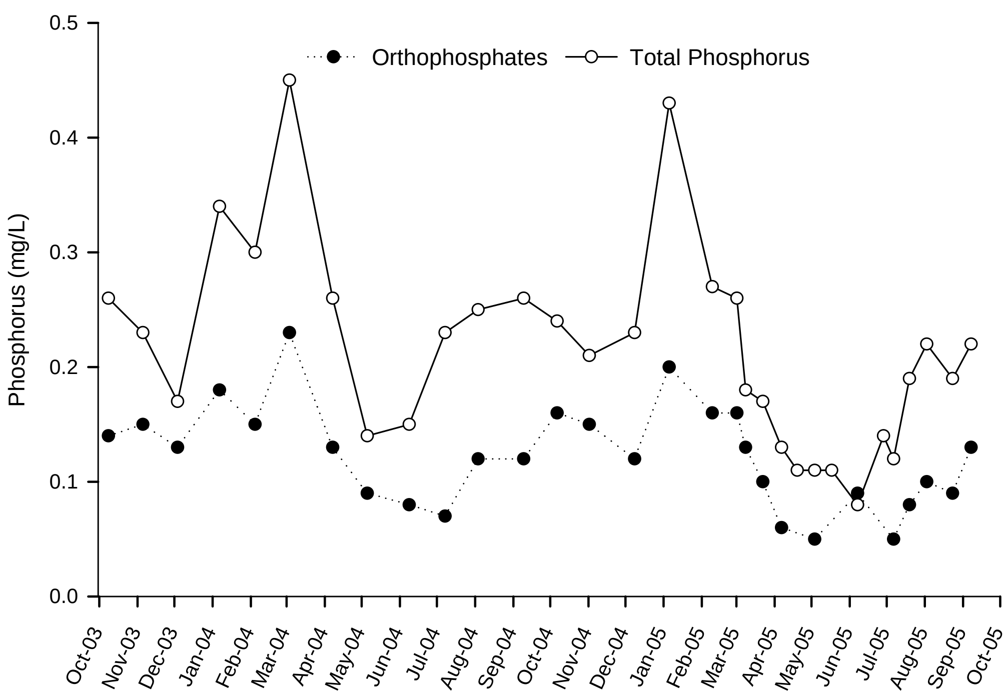


Figure 5-6 Nutrient concentrations at two Delta channel stations

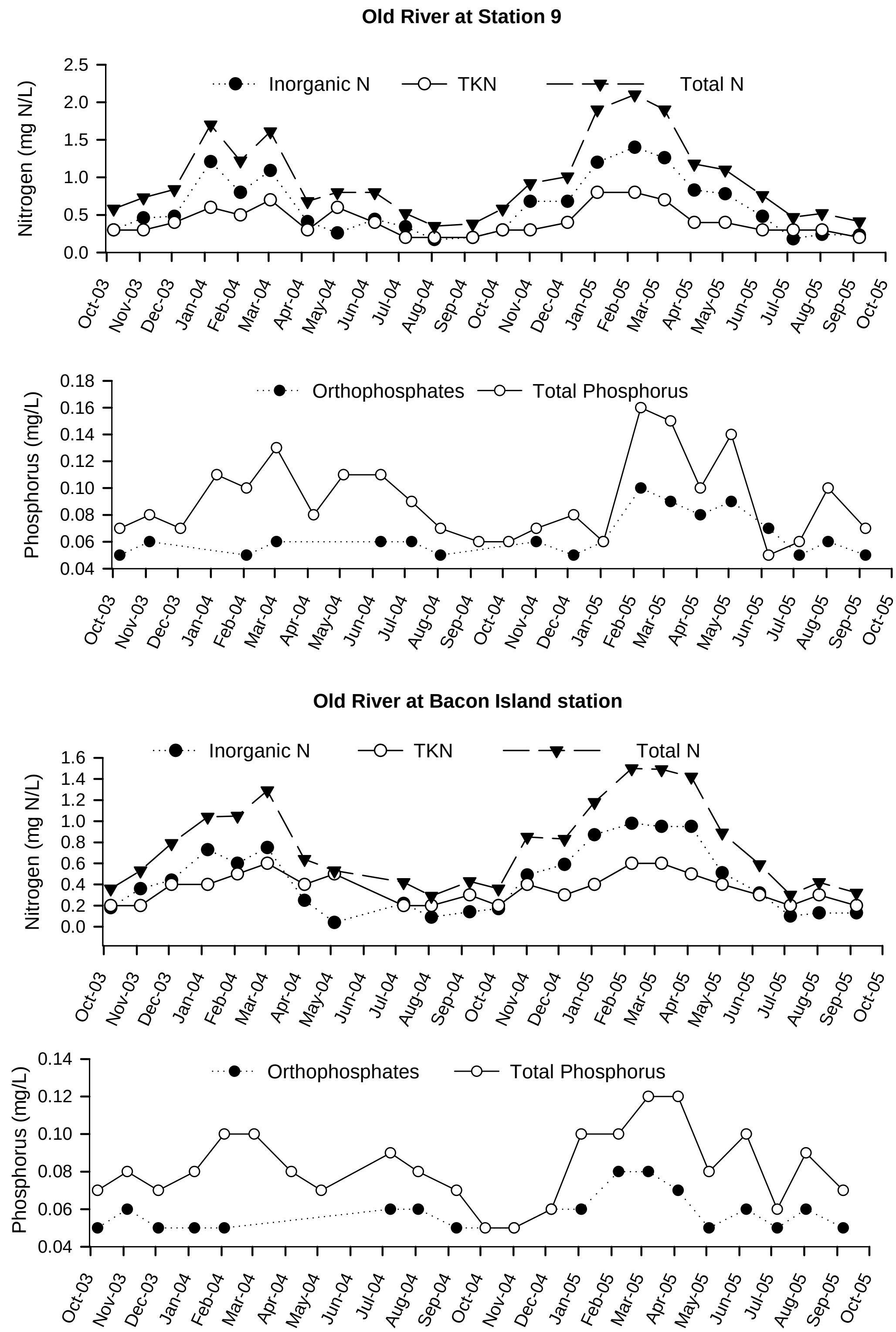


Figure 5-7 Nutrient concentration at two Delta diversion stations

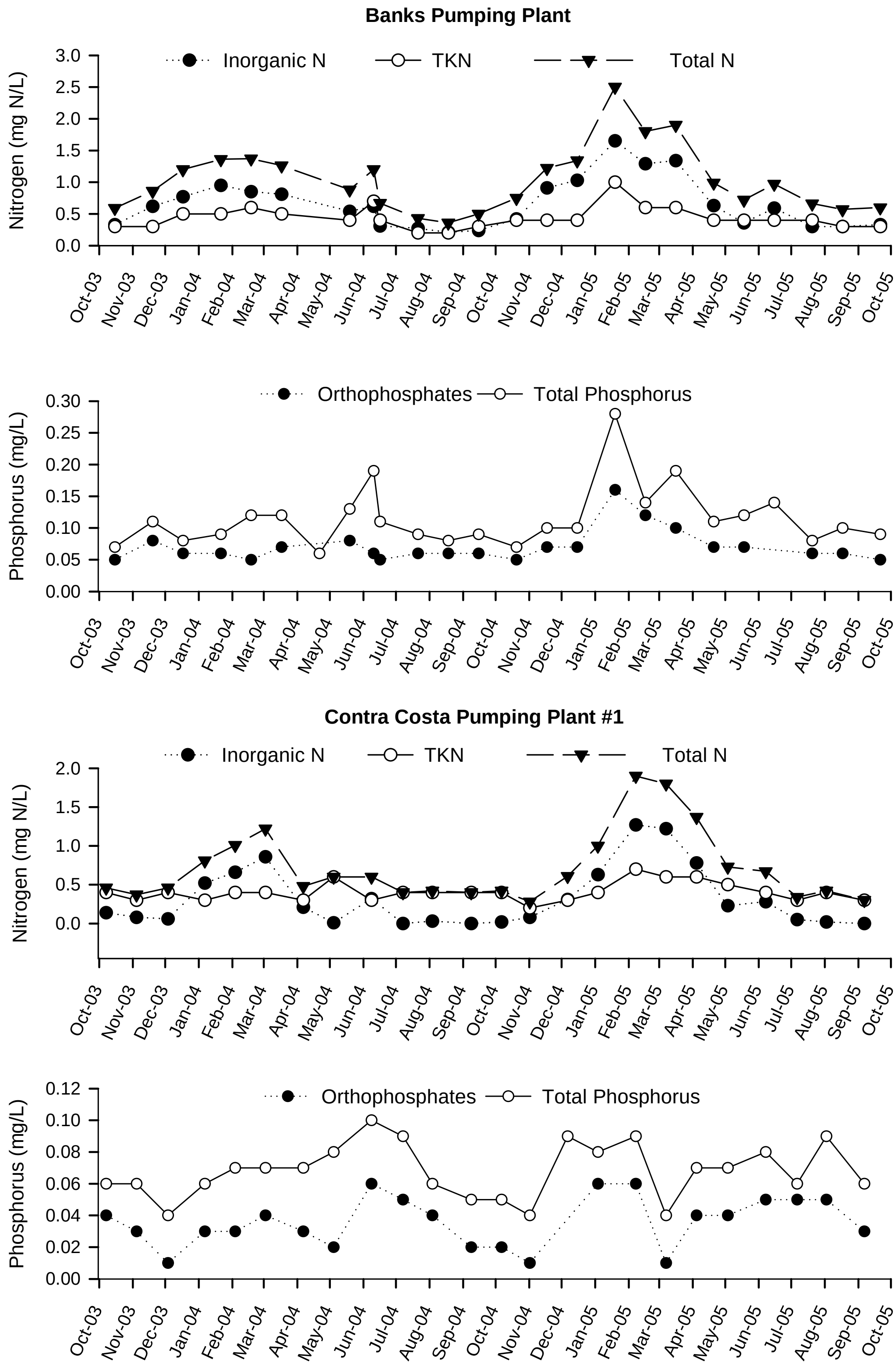


Figure 5-8 Nutrient concentrations at Mallard Island

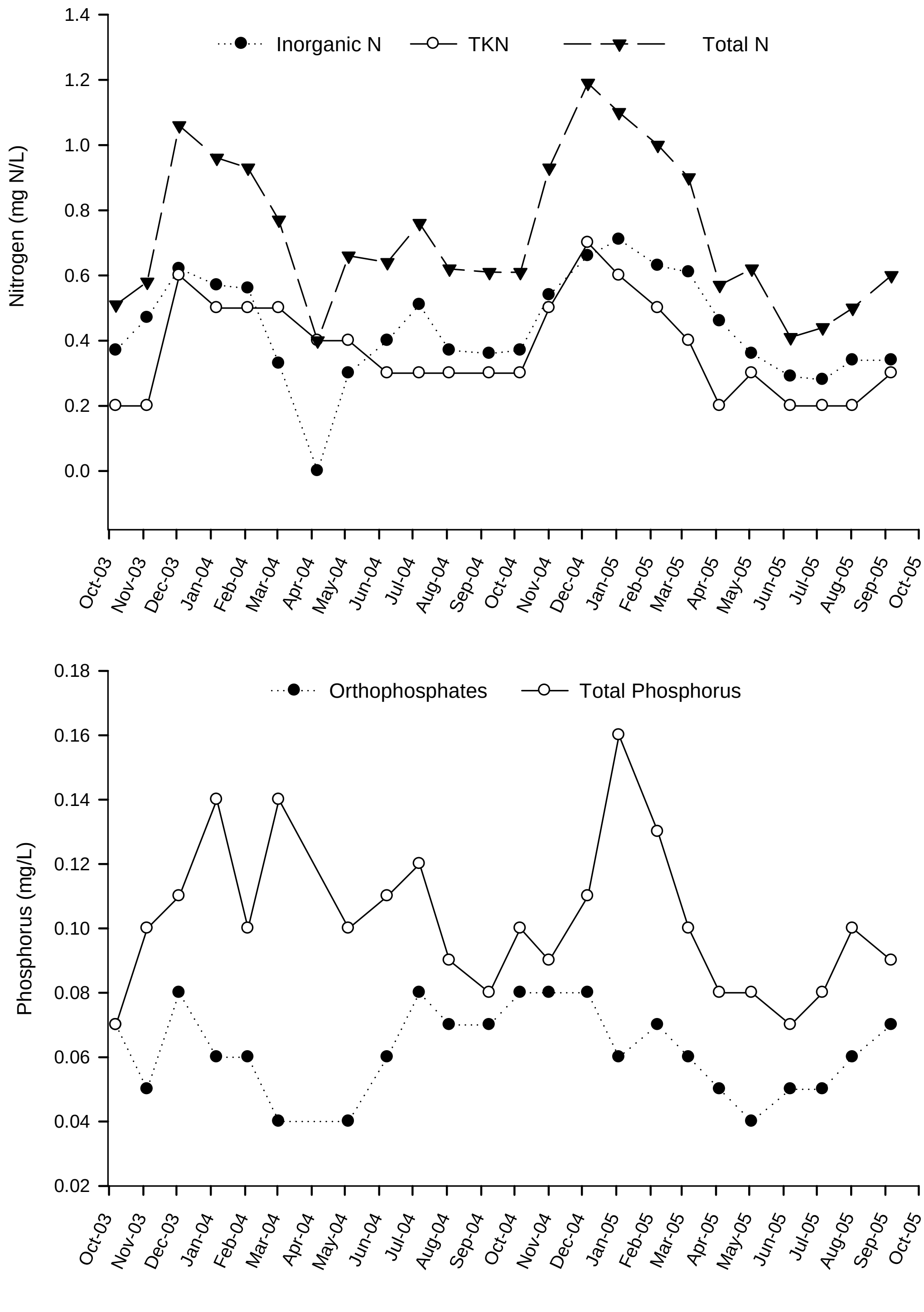


Table 5-1 Summary of inorganic, organic, and total nitrogen, Oct 2003 through Sep 2005

	Inorganic N *			Total Kjeldahl nitrogen (TKN)			Total nitrogen **		
	Range	Average	Median	Range	Average	Median	Range	Average	Median
Station		mg/L as N			mg/L as N			mg/L as N	
Stations north of the Delta									
American River at E.A. Fairbairn WTP	0.00–0.36	0.08	0.05	0.1–0.3	0.2	0.2	0.00–0.58	0.17	0.13
West Sacramento WTP Intake	0.05–0.42	0.16	0.13	0.1–0.5	0.2	0.2	0.05–0.75	0.33	0.27
Natomas East Main Drainage Canal	0.39–3.85	1.55	1.22	0.5–2.0	0.9	0.9	1.07–4.71	2.42	2.20
Sacramento River at Hood	0.19–1.01	0.51	0.47	0.3–1.1	0.6	0.5	0.40–1.30	0.74	0.72
San Joaquin River near Vernalis	0.00–2.79	1.48	1.50	0.2–1.7	0.7	0.6	0.38–3.93	2.13	2.30
Channel and diversion stations									
Old River at Station 9	0.17–1.40	0.60	0.47	0.2–0.8	0.4	0.4	0.35–2.10	0.96	0.8
Old River at Bacon Island	0.04–0.98	0.43	0.36	0.2–0.6	0.4	0.4	0.29–1.50	0.76	0.64
Banks Pumping Plant	0.21–1.65	0.64	0.59	0.2–1.0	0.4	0.4	0.28–2.50	1.00	0.88
Contra Costa Pumping Plant	0.00–1.27	0.32	0.18	0.2–0.7	0.4	0.4	0.28–1.90	0.71	0.54
Mallard Island	0.00–0.71	0.44	0.39	0.2–0.7	0.4	0.3	0.40–1.19	0.72	0.63

* Inorganic N includes ammonia, nitrate and nitrite.

** Total nitrogen includes TKN and nitrate and nitrite.

Table 5-2 Summary of orthophosphates and total phosphorus data at 10 MWQI stations

Station	Orthophosphates				Total Phosphorus			
	Positive detects/ sample number	Range	Average	Median	Positive detects/ sample number	Range	Average	Median
		--------- mg/L ---------				-------- mg/L -----------		
Stations north of the Delta								
American River at E.A. Fairbairn WTP	3/24	0.01–0.05	0.02	0.01	20/24	0.01–0.09	0.02	0.02
West Sacramento WTP Intake	24/24	0.01–0.06	0.03	0.03	24/24	0.04–0.12	0.07	0.07
Natomas East Main Drainage Canal	34/35	0.04–1.20	0.36	0.23	35/35	0.02–1.33	0.48	0.36
Sacramento River at Hood	31/31	0.02–0.11	0.06	0.06	31/31	0.05–0.15	0.09	0.09
San Joaquin River near Vernalis	30/31	0.04–0.23	0.12	0.12	31/31	0.08–0.45	0.21	0.22
Channel and diversion stations								
Old River at Station 9	24/24	0.04–0.10	0.06	0.06	24/24	0.05–0.16	0.09	0.08
Old River at Bacon Island	23/23	0.02–0.08	0.05	0.05	23/23	0.05–0.12	0.08	0.08
Banks Pumping Plant	25/25	0.03–0.16	0.07	0.06	25/25	0.06–0.28	0.11	0.10
Contra Costa Pumping Plant	23/24	0.01–0.06	0.04	0.04	24/24	0.04–0.10	0.07	0.07
Mallard Island	23/23	0.04–0.08	0.06	0.06	23/23	0.07–0.16	0.10	0.10

Chapter 6 Salinity

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Chapter 6 Salinity

Salinity is the amount of dissolved minerals in water and is measured by electric conductivity (EC) and total dissolved solids (TDS). TDS is measured directly in the laboratory or estimated from electrical conductivity (EC) values by use of a formula. High levels of salinity cause objectionable taste in drinking water. The State of California established specific secondary drinking water standards for salinity (Appendix Table A-3). These State secondary standards are enforceable.

EC = electrical conductivity

TDS = total dissolved solids

Appendix Table A-3

During the reporting period from October 2003 through September 2005, Municipal Water Quality Investigations (MWQI) sampled 10 stations, which were divided into five groups: stations north of the Delta, Sacramento River at Hood, San Joaquin River near Vernalis, channel and diversion stations and Mallard Island. The stations north of the Delta include American River at E.A. Fairbairn WTP, West Sacramento WTP Intake, and Natomas East Main Drainage Canal (NEMDC). The channel and diversion stations consist of two channel stations, Old River at Station 9 and Old River at Bacon Island, and two diversion stations, Banks Pumping Plant and Contra Costa Pumping Plant. All stations were sampled weekly, biweekly, or monthly. This chapter presents salinity of Delta source waters measured as EC, TDS, chloride, and sulfate.

MWQI = Municipal Water Quality Investigations

SJR = San Joaquin River

WTP = water treatment plant

NEMDC = Natomas East Main Drainage Canal

Stations North of the Delta

American River at E.A. Fairbairn WTP

EC of the American River at E.A. Fairbairn WTP ranged between 42 and 74 µS/cm with an average of 61 and a median of 63 µS/cm (Table 6-1). Out of the 10 MWQI stations, the American River station displayed the lowest EC and TDS values. Overall, both EC and TDS were higher during the below normal 2004 Water Year than during the above normal 2005 WY (Figure 6-1). However, there was no significant statistical difference in EC between the 2 water years ($p = 0.519$). EC and TDS concentrations were lower in the 2004 and 2005 WYs than during the 2002 and 2003 WYs. Overall the Fairbairn WTP has the lowest salinity concentrations of all the stations sampled (see Figure 6-1).

WTP = water treatment plant

Table 6-1 Summary of EC and TDS data, Oct 2003 through Sep 2005

WY = water year

Figure 6-1 EC and TDS at the E.A. Fairbairn WTP Intake

Sacramento River at West Sacramento WTP Intake

West Sacramento WTP Intake station measures EC and TDS of the Sacramento River after it has passes through the agricultural region of the northern Sacramento Valley. The ranges for EC and TDS were 119 to 240 µS/cm and 69 to 147 mg/L, respectively. The average EC was 171 and the median EC was 166 µS/cm. The average and median for TDS were 100 and 96 mg/L, respectively (see Table 6-1). Seasonality of both EC and TDS are related to the amount of runoff from the contributing watersheds. EC increased during the wet months and decreased during the dry months according to the seasonal averages and medians (Figure 6-2). Values of EC were elevated in response to rainfall events during the wet months; however, EC fluctuated during the dry months in response to urban and agricultural drainages. Despite the increase in salinity during the above normal 2005 WY in comparison to the 2004 below normal WY, EC and TDS increased in June and September of both WYs, possibly due to rice drainage from the Sacramento Valley.

mg/L = milligrams per liter

Figure 6-2 EC and TDS at the West Sacramento WTP Intake

Natomas East Main Drainage Canal

NEMDC collects urban runoff from a heavily populated watershed that is rapidly expanding to the northern boundary of the Delta in northern Sacramento. Even though NEMDC is near the American River at the E.A. Fairbairn WTP and the Sacramento River at the West Sacramento WTP Intake, the averages and medians of EC and TDS at NEMDC were considerably higher than at those two stations. This is because of urban runoff, wastewater treatment plant discharges, and other mixed land use drainage that comprise NEMDC flows.

During the two water years, a total of 36 grab samples were taken at NEMDC. The range of EC was from 96 to 509 µS/cm, while the average and median EC were 296 and 294 µS/cm, respectively. Average and median TDS concentrations were 180 and 186 mg/L. A strong seasonal pattern was not observed; however, EC and TDS were much lower during or immediately after a sustained heavy rainfall (Figure 6-3). Very low TDS values were observed during significant storm events in January to February 2004, November to December 2004, and January to February of 2005. Both EC and TDS increased slightly during the dry months, especially during the 2004 below normal WY.

Figure 6-3 EC and TDS in the NEMDC station

Sacramento River at Hood

Unlike the West Sacramento WTP Intake, the Sacramento River at Hood measures surface water that has been influenced by discharges from two major nearby wastewater treatment plants, urban drainage, and inflows from the American River. Therefore, the 72 EC samples ranged from 111 to 240 µS/cm and the 31 TDS samples ranged from 69 to 140 mg/L. The average and median EC values were 161 and 154 µS/cm, respectively, and the average and median TDS values were 97 and 93, respectively (see Table 6-1). Even though flows from the American River are generally small compared to the flows from the upper Sacramento River, EC and TDS at the Hood station were slightly lower than at the West Sacramento WTP Intake station, reflecting the beneficial influence of the American.

Seasonality of both EC and TDS appeared to have been related to the amount of runoff in the Sacramento Valley watershed. EC increased during the wet months and decreased during the dry months (Figure 6-4). Similar to that at the West Sacramento WTP Intake, EC at the Hood station was higher in the 2005 above normal WY than during the 2004 below normal WY. Regardless of the water years, EC and TDS increased in the dry months of June and October due to the irrigation and discharge from upstream agricultural fields during the growing season.

Figure 6-4 EC and TDS at Sacramento River at Hood

San Joaquin River near Vernalis

Both EC and TDS at the SJR near Vernalis were the second highest of the 10 stations monitored during the summary period, with the highest being the Mallard Island station, due to seawater influence. Electrical conductivity of SJR near Vernalis ranged from 120 to 1,170 µS/cm, with a median of 710 µS/cm (see Table 6-1).

Higher salinity at the Vernalis station occurs when releases from the east side reservoirs are reduced. Heavy rainfall in November 2004 and January 2005 caused the EC to decrease drastically, even though the EC generally remained higher during the remainder of wet months than during the dry months of each water year (Figure 6-5). Significant differences in EC were found between the dry months of 2004 and 2005 WYs as well as between the wet months of the 2004 and 2005 WYs (p = 0.0014 and 0.0037, respectively). The highest EC values occurred during the wet months of the 2004 dry runoff year in the San Joaquin Valley with a median EC of 858 µS/cm.

Figure 6-5 EC and TDS at the SJR near Vernalis

The lowest EC values in both water years were found during May through June. This decrease in EC was attributed to the implementation of the Vernalis Adaptive Management Plan (VAMP), mandated by the California State Water Resources Control Board Decision 1641. Due to VAMP, a pulse of fresh water is maintained for a minimum of 31 days from the rivers that bring water from the Sierra (DWR 2003).

VAMP = Vernalis Adaptive Management Plan

DWR. 2003. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected August 1998 to September 2001. July

Channel and Diversion Stations

Channel stations

Delta channel stations are located on the Old River at Station 9 and on the Old River at Bacon Island. According to the Mann-Whitney test, the EC at both stations was not significantly different (p =0.4095), even though Station 9 had a slightly higher average and median. EC and TDS levels were much lower than those at the SJR near Vernalis, but were approximately twice as high as the Sacramento River stations north of the Delta and at Hood (see Table 6-1). Unlike the stations along both the SJR and the Sacramento River, the two channel stations had EC that was not higher in the wet months in comparison with the dry months in the 2004 WY (Figure 6-6). EC and TDS at the channel stations were higher during the dry months of the 2004 WY and wet months of 2005 WY. These could be attributed to both the increase of total Delta outflow during the wet months of 2004 and reservoir releases during the dry months of 2005.

Figure 6-6 EC and TDS at the Delta channel stations

Although the majority of the water in Old River is a mixture from the two major river systems flowing into the Delta, the relative contribution from either river varies with hydrologic conditions and pumping regimes at the diversion stations along Old River. Seasonality is related directly to Delta outflow, which has a strong influence on EC levels. When Delta outflows are low, the tides can bring in water from the bay, ultimately increasing the EC levels. A small fraction of the water is agricultural drainage from various Delta islands, which also increases the EC of the channel stations.

Increased EC and TDS are found in the beginning of the wet months of both water years. This is attributed to increased salts entering the rivers as a result of runoff from increased precipitation (see Figure 2-2). However, as precipitation increases during the wet months, increased runoff from the watersheds of the contributing rivers diluted the Delta channel waters (see Figure 6-6). In the dry months, river flows decreased and salinity in the rivers increased causing an increase in salinity at the channel stations. Even with reservoir releases throughout the dry months, EC and TDS increase due to returned irrigation water from the agricultural growing season.

EC and TDS were measured at Station 9 with medians of 354 µS/cm and 219 mg/L, respectively (Table 6-1). Bacon Island's EC and TDS medians were consistent with those of Station 9 at 339 µS/cm and 210 mg/L, respectively. Even though Bacon Island's readings were lower than those of Station 9, the two stations were not significantly different ($p = 0.4095$). Due to the difference in water year types, the dilution period for EC and TDS was extended from the wet months farther into the dry months of the 2005 WY before the seasonal EC and TDS increase (see Figure 6-6). The difference in EC between wet and dry months in 2005 was significantly different ($p = 0.0225$), while difference in EC between the wet and dry months of 2004 was not significantly different ($p = 0.2824$).

Diversion Stations

The diversion stations are the Banks and Contra Costa Pumping Plants. Of the two, the Contra Costa Pumping Plant had the higher values, with a median EC and TDS of 485 µS/cm and 272 mg/L, respectively. The Banks EC and TDS medians were 350 µS/cm and 204 mg/L, respectively (see Table 6-1). Even though seasonal patterns of EC and TDS were similar to those at the two Old River stations, both EC and TDS at the diversion stations were generally higher than those found at the two Old River stations (Figures 6-6 and 6-7). EC and TDS averages and medians were lower than during the previous reporting period. Of the 2 diversion stations, Contra Costa Pumping Plant is closer to Suisun Bay and is therefore affected by seawater intrusion into the Delta. Consequently, during the wet months of the sampling period, median EC and TDS values were generally higher at the Contra Costa Pumping Plant than at Banks Pumping Plant (see Figure 6-7).

Figure 6-7 EC and TDS at the Delta diversion stations

Mallard Island

Of all 10 MWQI sampling stations, Mallard Island station is the closest to Suisun Bay and is highly affected by tidal events and seawater intrusion. Mallard Island station's EC and TDS values were, therefore, the most elevated out of the 10 stations, which is consistent with findings from the previous reporting period. During the two-year reporting period, the range of EC was from 150 to 14,460 µS/cm, with an average and median EC of 5,347 and 4,190 µS/cm, respectively (see Table 6-1). TDS ranged from 90 to 9,600 mg/L, with an average and median of 3,167 and 2,380 mg/L, respectively (see able 6-1).

EC and TDS values at Mallard Island can be directly correlated with the total Delta outflow. EC was higher at the beginning of the wet months during each water year, but as precipitation in the contributing watersheds continued, EC and TDS decreased reflecting increased Delta outflow (Figure 6-8). During the dry months of 2004, when the total Delta outflow was very low, EC and TDS values were elevated; however, a decrease in salinity resulted from increased releases of water from peripheral reservoirs. EC levels between January and September were lower for a longer period in 2005 WY than in 2004 WY (Figure 6-8); however, there was no statistical difference between the two water years ($p = 0.1858$).

Figure 6-8 EC and TDS at the Mallard Island station

Chloride and Sulfate

Chloride and sulfate affect the taste and odor of finished drinking water; therefore, an MCL of 250 mg/L for both constituents was established by federal and State regulations (see Appendix Table A-3). Both chloride and sulfate add to the total mineral content of water, thereby affecting EC. At elevated concentrations, chloride gives water a brackish or harsh taste.

Drinking water providers report increased taste and odor complaints from customers when chlorides are greater than 100 mg/L (Holm 2003 pers comm). Although concentrations of chloride and sulfate in source waters of the Delta do not represent those of finished drinking waters, chloride and sulfate data are briefly summarized here for reference.

Holm L. 2003. Review comments on draft MWQI 3-year summary [DWR 2003]

Chloride and sulfate levels were generally low at most stations except at the Mallard Island station (Table 6-2). Chloride at the Mallard Island station was high and frequently exceeded the MCL of 250 mg/L, due to seawater influence. Chloride at Mallard Island ranged from 7 to 5,360 mg/L with a median of 417 mg/L. Sulfate was occasionally above the MCL at Mallard Island. Sulfate ranged from 9 to 634 mg/L, with a median of 68 mg/L (Table 6-2). During the reporting period, both chloride and sulfate were generally low at this station. Average chloride and sulfate were 60 and 35 mg/L, respectively; and median chloride and sulfate were 53 and 27 mg/L, respectively (Table 6-2). These values were well below their secondary standards set by the State for chloride and sulfate (Appendix A, Table A-3).

Table 6-2 Summary of chloride and sulfate data, Oct 2003 through Sep 2005

Agricultural drainage waters, which often contain higher levels of chloride and sulfate, affect the stations on the SJR and Old River, but they have not raised the concentrations of chloride and sulfate near or above their MCLs. Agricultural return water is a relatively small fraction of the water in the SJR and in Old River; therefore, chloride and sulfate in these river stations remained low despite these discharges.

At NEMDC, the concentrations of both chloride and sulfate in its urban drainage were low (see Table 6-2). Chloride and sulfate concentrations were higher at NEMDC than at the American River at E.A. Fairbairn WTP, the Sacramento River at Hood, and the West Sacramento WTP Intake, but lower than at all other stations (see Table 6-2).

Salinity of Delta Waters between Current Reporting Period and Previous Periods

Sacramento River at Hood

Of the 3 recent reporting periods, EC at this station was slightly higher in the 2002-2003 period, while EC for the 1999-2001 and 2004-2005 periods were similar (Table 6-3). Seasonality of both EC and TDS were related to the amount of runoff in the contributing watersheds in all three sampling periods. The 1999-2001 summary period was composed of 3 water years, which began with a wet water year, followed by an above normal water year, and ended with a dry water year. EC and TDS were elevated during the wet months of the 2001 dry WY. Of the three-year sampling period (1999-2001), the 2001 WY had the highest median EC of 188 µS/cm. The 2002 year was also a dry water year; however, the EC decreased to a median of 165 µS/cm. Even though the 2003 WY was classified as above normal, EC levels increased in the wet months of both the 2002 dry WY and the 2003 above normal WY. Values of EC were elevated and variable in response to rainfall events during the wet months, especially in the dry 2002 WY. During the current period, EC was higher in the drier 2004 runoff year and lower in the

Table 6-3 Summary of salinity during three consecutive sampling periods

wetter 2005 runoff year. The 2004 below normal WY had a median EC that remained the same during both dry and wet months. In the 2005 above normal WY, however, EC increased in the wet months. The highest EC values in all three sampling periods were found in the wet months of the drier runoff years. The lowest EC values were found in the dry months of the wetter runoff year with the exception of the 1999-2001 sampling period. The lowest EC for the 1999-2001 sampling period was found during the wet months of the wet 1999 WY.

San Joaquin River near Vernalis

Of the 3 sampling periods, the 2002–2003 reporting period had the highest EC and TDS values (Table 6-3). Higher EC and salinity during the 2002-2003 sampling period was attributed to reduced inflows to the SJR. The previous summary period, 1999–2001, was preceded by 2 wet runoff years (1997 and 1998) and started with 2 above normal runoff years (1999 and 2000), followed by a dry runoff year (2001). In contrast, the 2002–2003 reporting period was preceded by a dry runoff year (2001) and began with a dry runoff year (2002), which was followed by a below normal runoff year (2003). Consequently, inflows to the SJR above Vernalis were higher during the previous summary period than during the 2002–2003 reporting period resulting in EC increases for the 2002–2003 reporting period.

As with the 2002–2003 reporting period the 2004–2005 sampling period was preceded by a dry year and began with a dry year. The highest levels of EC were found in the dry 2004 WY during the wet months; however, the lowest ECs were reported during the dry months of the wet water year. For the 2002–2003 reporting period the highest EC and the lowest EC were found in the wet months of the dry 2002 WY. The EC levels were also the highest during the wet season of the below normal 2003 WY. Both EC and TDS were generally higher during the wet months than during dry months of each water year. EC and TDS were higher during the dry 2001 WY than during the previous 2 water years because of lower watershed runoff.

Banks Station

The 1999–2001 and the 2002–2003 reporting periods had similar medians for EC (384 µS/cm and 387 µS/cm); however, the 2004–2005 reporting period had a lower median EC (350 µS/cm, respectively). The increase and decrease in EC is directly related to the magnitude of Delta outflows during the three summary periods, which was dependent on the runoff year types in the two major contributing watersheds. EC for the 2004–2005 reporting period was higher in the wet months of 2004 WY and during the dry months of 2005 WY. EC for the 2002–2003 reporting period was higher in the dry months of the 2002 WY and during the wet months of the 2003 WY. EC and TDS were consistently higher during the wet months than the dry months of the 1999–2001 sampling period. In all three reporting periods Delta total outflow increased in the wet months and generally decreased in the dry months.

Summary

Among the 10 MWQI stations, the American River at E.A. Fairbairn WTP displayed the lowest EC with a median of 63 µS/cm (Figure 6-9). Median EC at the Sacramento River at West Sacramento WTP Intake was 166 µS/cm. Median EC at NEMDC was 294 µS/cm, but median flow at NEMDC was less than 1% of the combined flows from Sacramento and American Rivers. Median EC at Sacramento River at Hood was 154 µS/cm, which represented salinity in northern Delta inflows (see Figure 6-9). EC of the SJR was much higher than those found in the American or Sacrament Rivers. Median EC at SJR near Vernalis was the second highest of the 10 monitored stations (see Figure 6-9). High levels of salts in the irrigation returns from the San Joaquin Valley and recirculation of salts from the Delta ultimately increased EC levels.

Figure 6-9 Electrical conductivity: Range, median (unit µS/cm)

EC was significantly lower at the Delta channel and diversion stations than at the SJR due to the dilution effects of water from the Sacramento River. Median EC at the Delta channel stations was 354 µS/cm for Old River at Station 9 and 339 µS/cm for Old River at Bacon Island. EC was higher at one of the diversion stations, the Contra Costa Pumping Plant, where the median was 485 µS/cm (Figure 6-9). Of all 10 MWQI sampling stations, Mallard Island had the highest salinity concentration because it is close to Suisun Bay and subject to tidal events and seawater intrusion. Seawater influence was the primary source of salinity throughout the western Delta as indicated by the high median EC of 4,190 µS/cm at Mallard Island (see Figure 6-9).

From the northern rivers to the SJR and throughout the Delta, salinity is affected by watershed runoff, urban discharges and agricultural drainage. Seasonal precipitation during wet months and reservoir releases during dry months decrease salinity by diluting the water with low mineral content. However, salinity loads from the watersheds were significant during the wet months, especially after the first few major rain events.

Chapter 6 Salinity

Figures

Tables

Figure 6-1 EC and TDS at E.A. Fairbairn WTP Intake

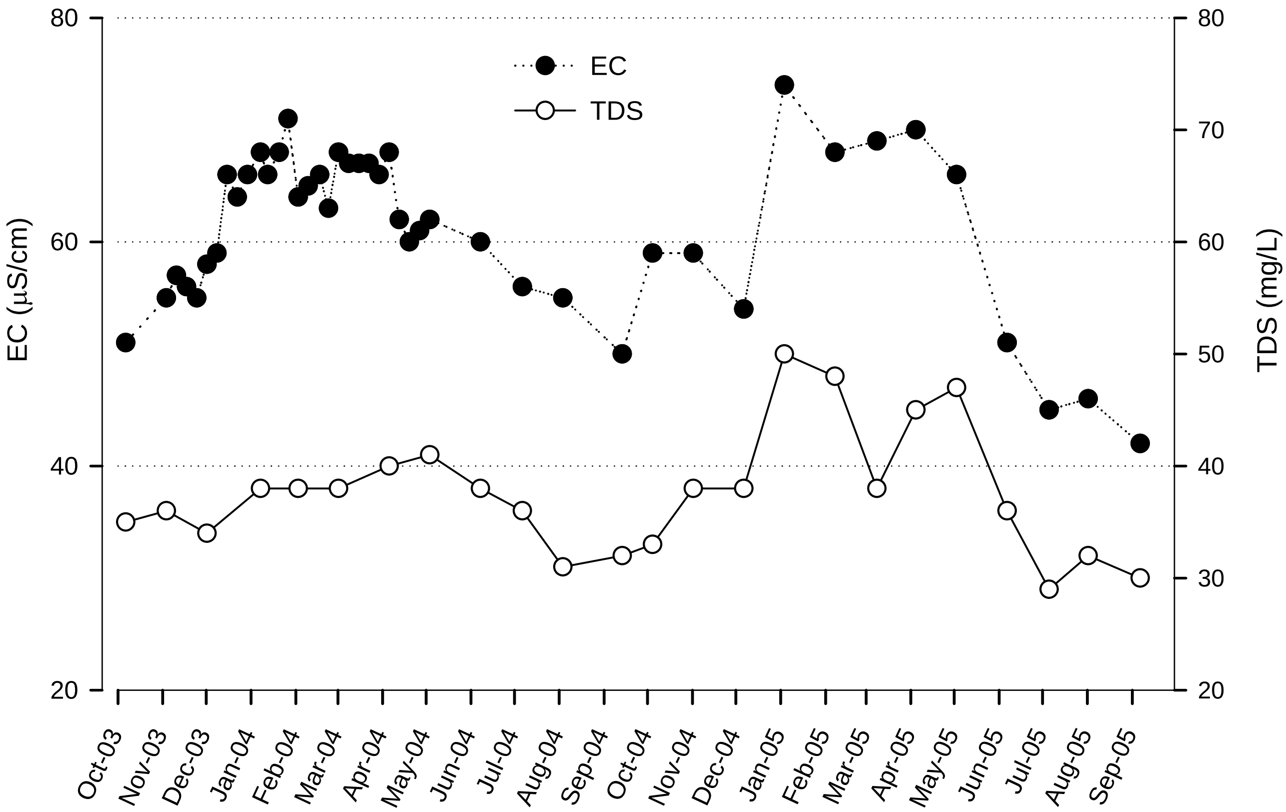

Figure 6-2 EC and TDS at West Sacramento WTP Intake

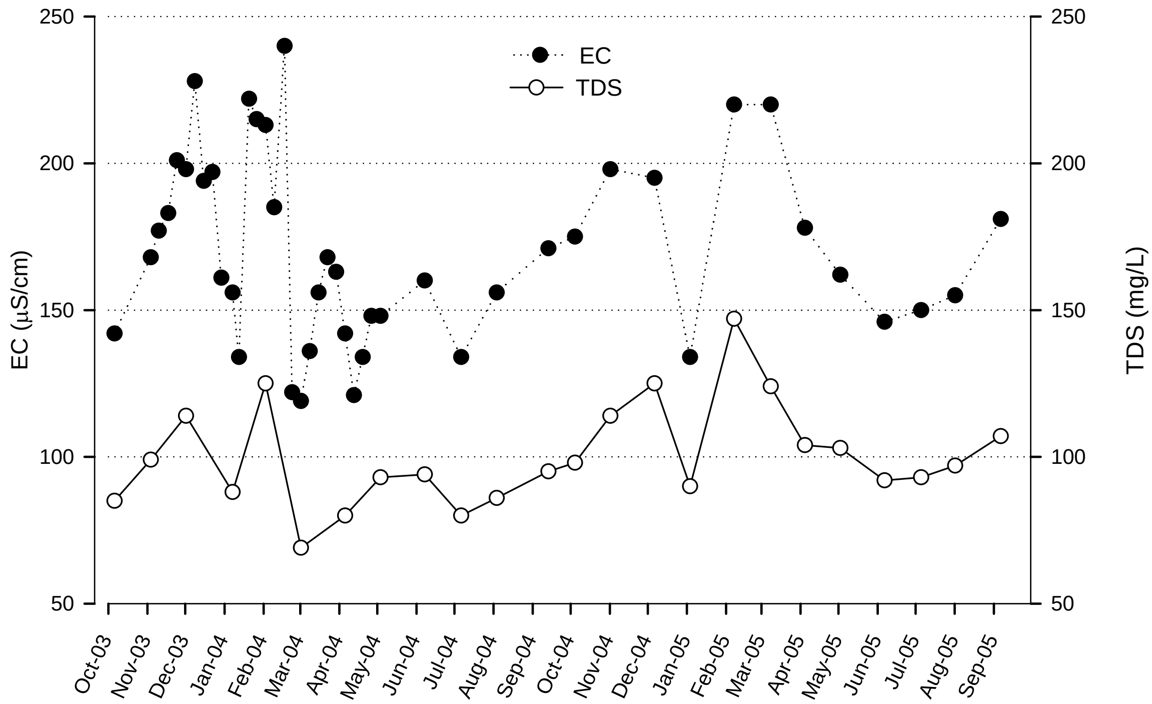

Figure 6-3 EC and TDS in the NEMDC station

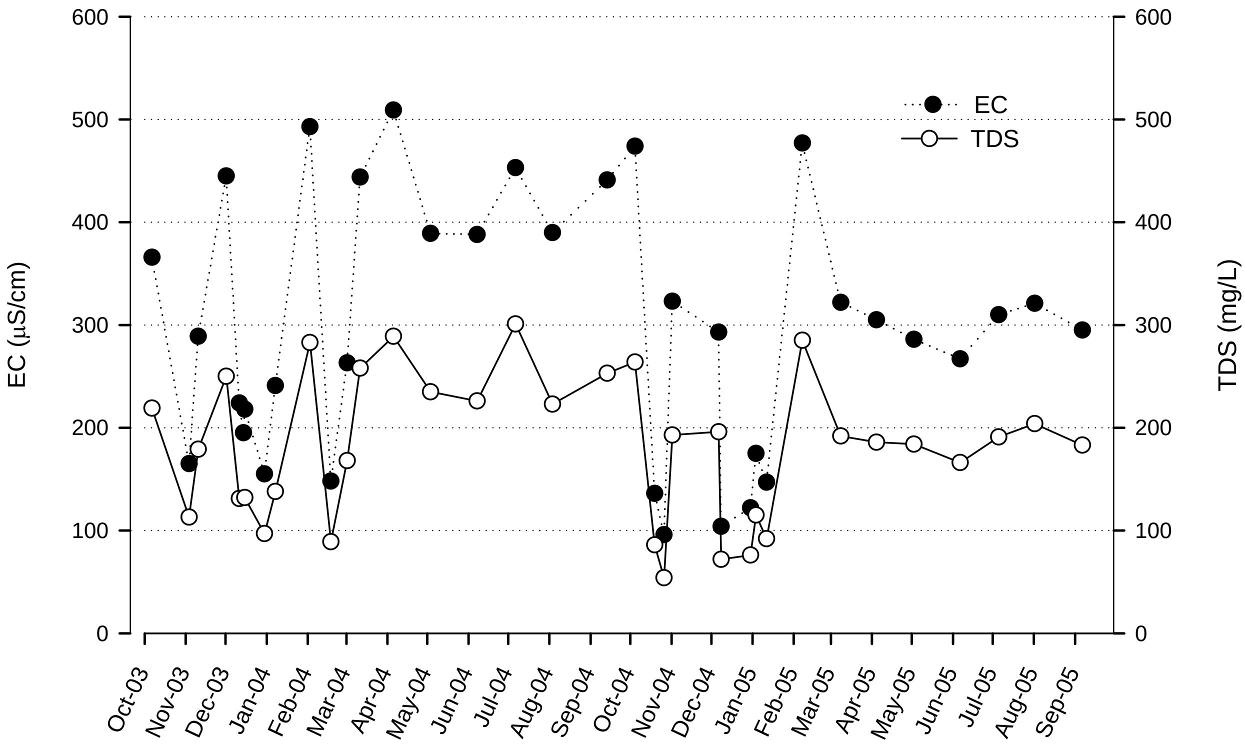

Figure 6-4 EC and TDS at Sacramento River at Hood

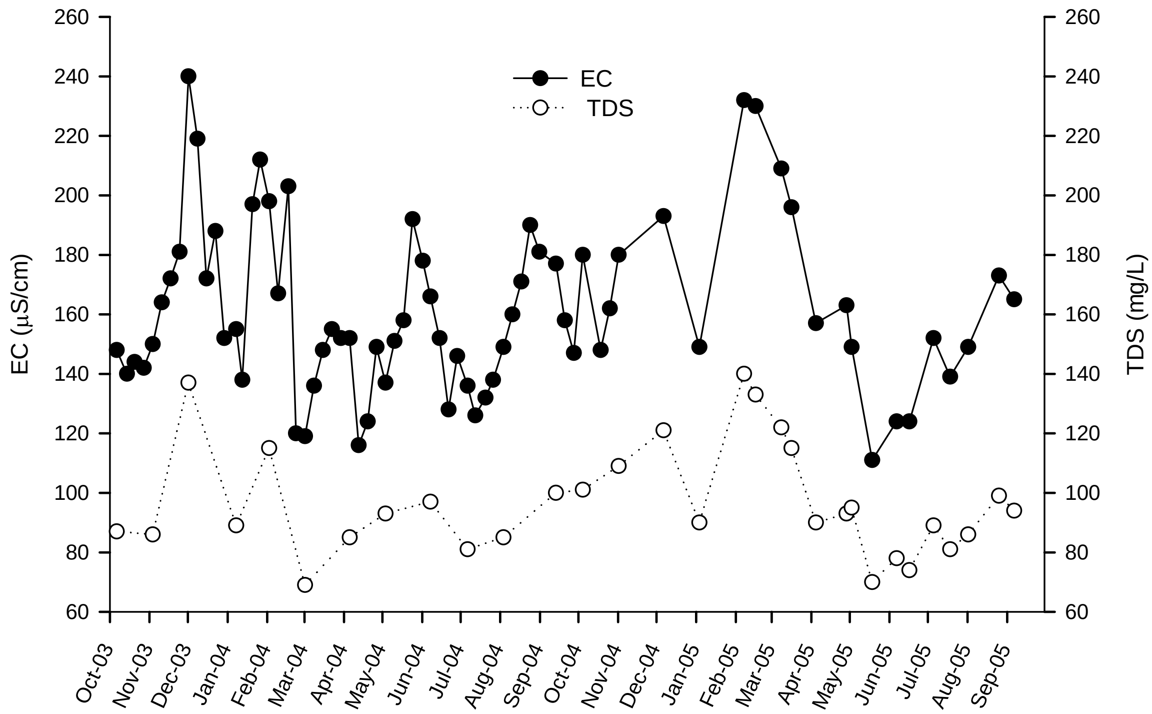

Figure 6-5 EC and TDS at the San Joaquin River near Vernalis

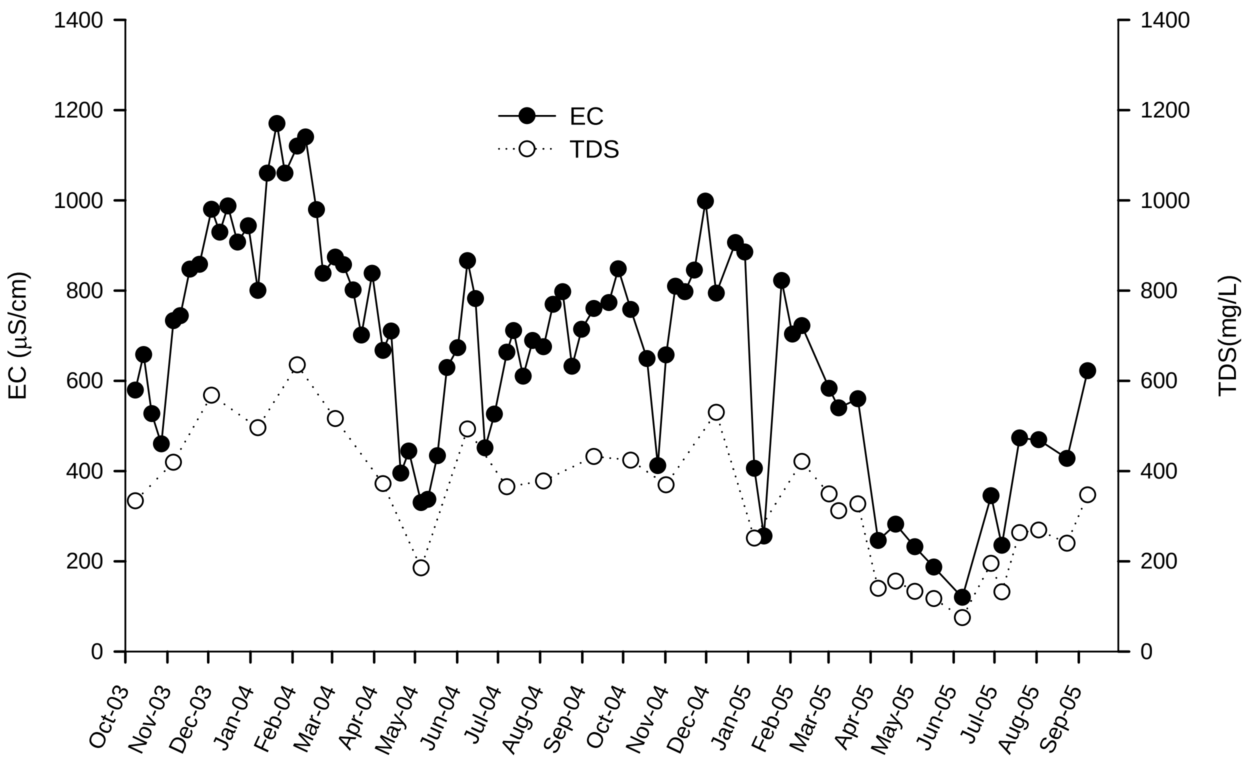

Figure 6-6 EC and TDS at the Delta channel stations

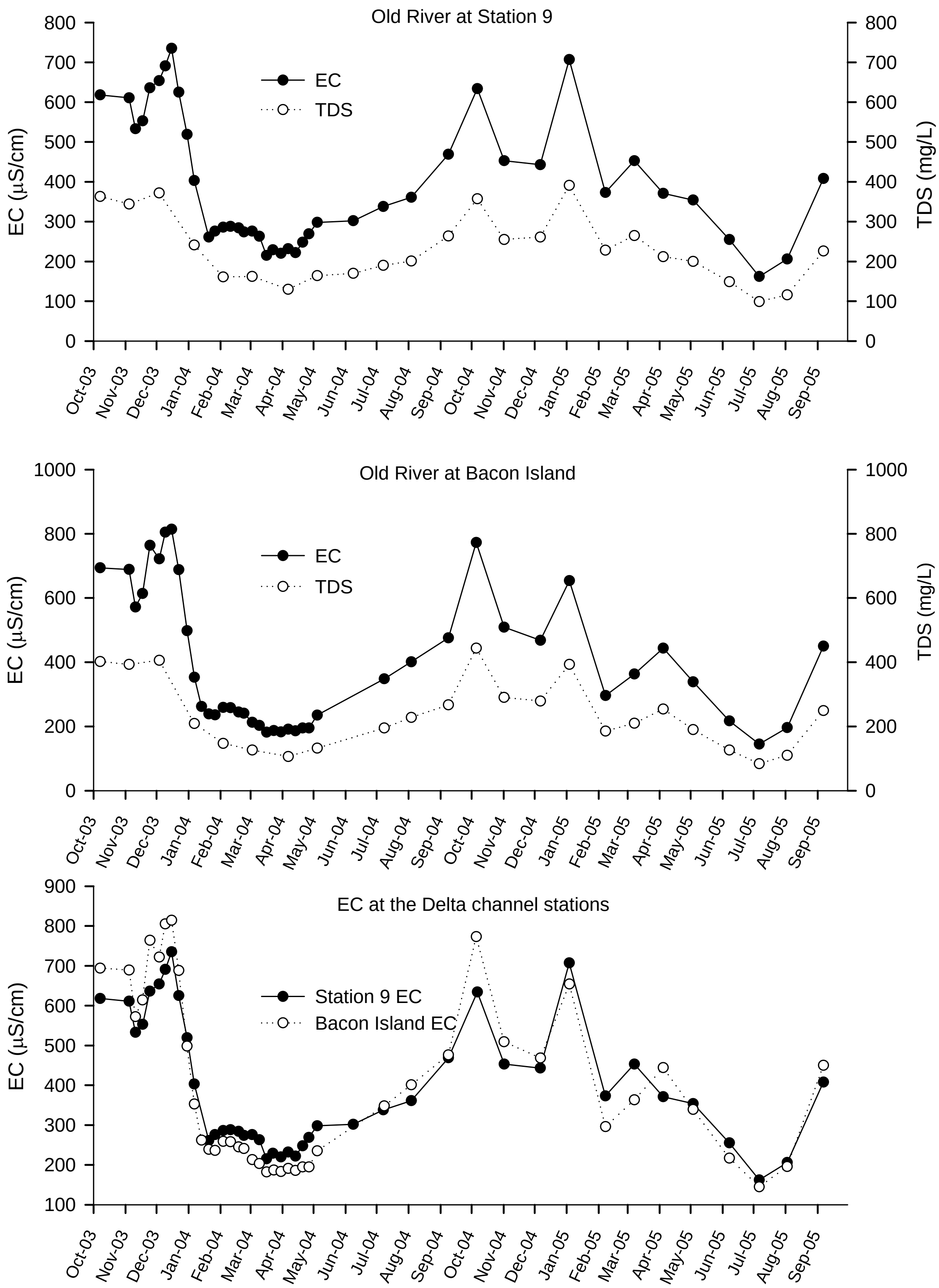

Figure 6-7 EC and TDS at Delta diversion stations

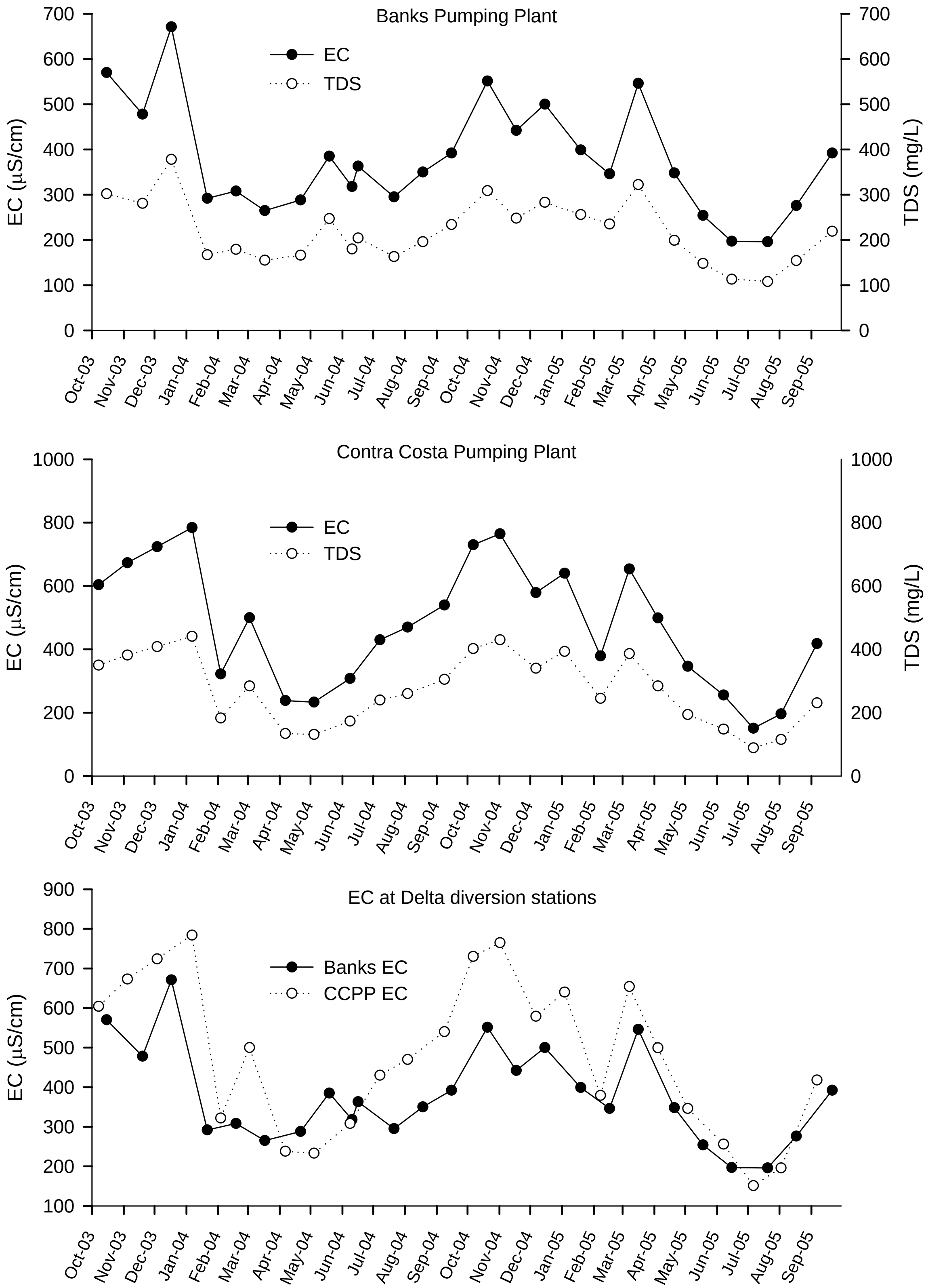

Figure 6-8 EC and TDS at the Mallard Island station

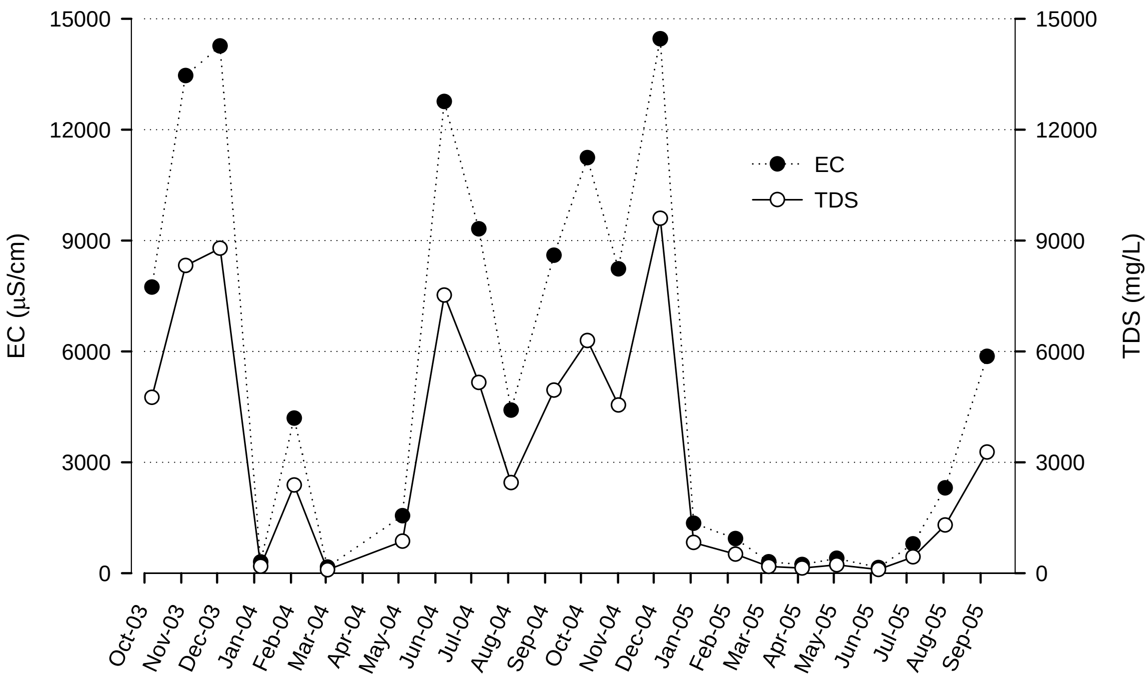

Figure 6-9 Electrical conductivity: Range, median (unit µS/cm)

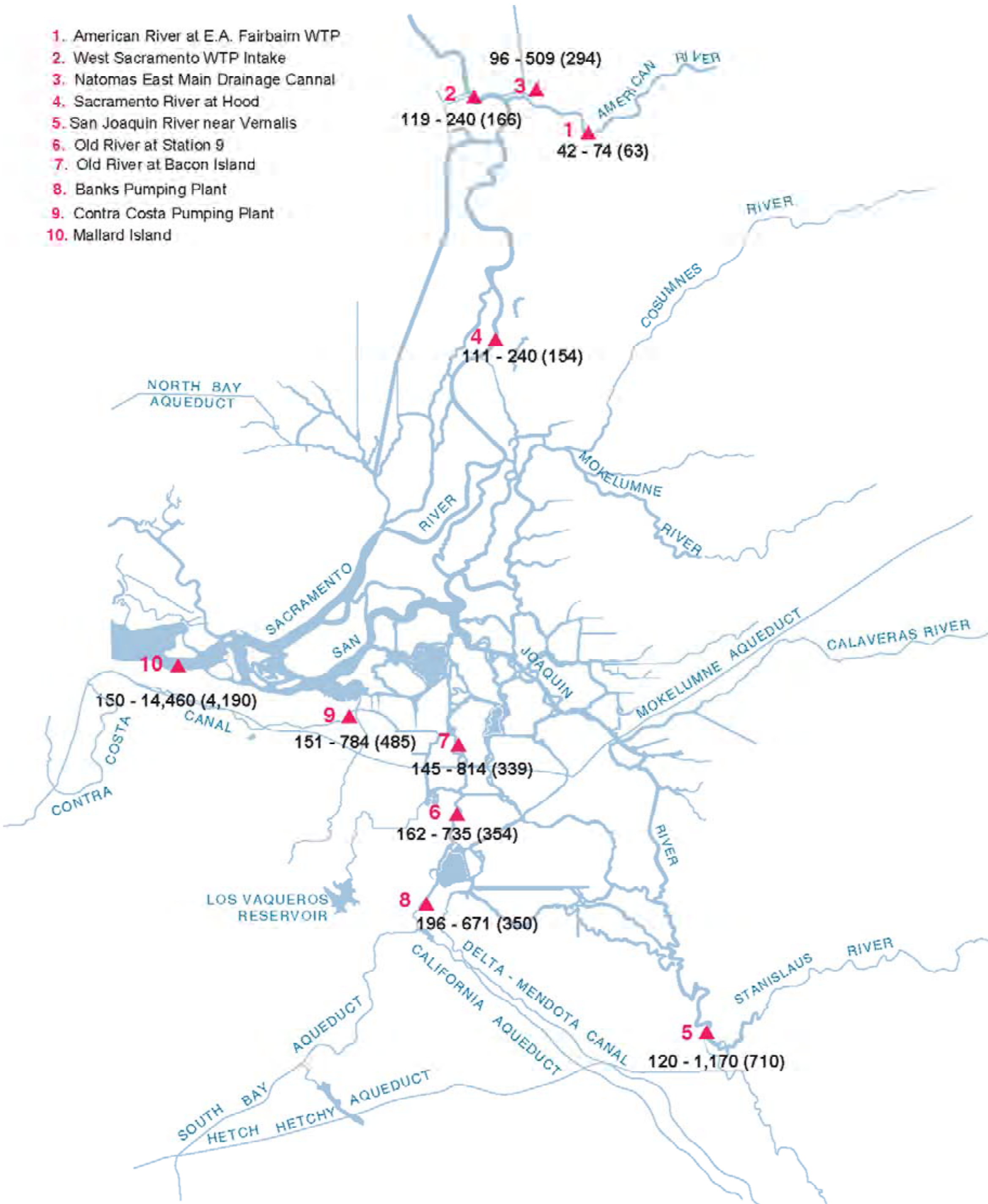

Table 6-1 Summary of EC and TDS data, Oct 2003 through Sep 2005

	EC (µS/cm)				TDS (mg/L)			
Station	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
Stations north of the Delta								
*American River at E.A. Fairbairn WTP	44	42–74	61	63	24	29–50	38	38
*West Sacramento WTP Intake	44	119–240	171	166	24	69–147	100	96
*Natomas East Main Drainage Canal	36	96–509	296	294	35	54–289	180	186
***Sacramento River at Hood**	72	111–240	161	154	31	69–140	97	93
San Joaquin River near Vernalis	81	120–1,170	679	710	31	75–635	330	347
Channel and diversion stations								
Old River at Station 9	43	162–735	396	354	24	99–391	230	219
Old River at Bacon Island	43	145–814	395	339	23	84–444	236	210
Banks Pumping Plant	25	196–671	377	350	25	108–378	218	204
Contra Costa Pumping Plant	24	151–784	477	485	24	89–441	273	272
Mallard Island	23	150–14,460	5,347	4,190	23	90–9,600	3,167	2,380

*Measurements of EC and TDS on 07/06/2004 at the four stations were erroneous; therefore, field EC was used instead.
TDS was calculated based on the empirical relationship between EC and TDS at each of the four stations.

Table 6-2 Summary of chloride and sulfate data, Oct 2003 through Sep 2005

	Chloride (mg/L)				Sulfate (mg/L)			
Station	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
Stations north of the Delta								
American River at E.A. Fairbairn WTP	27	1–3	2	2	24	1–4	2	2
West Sacramento WTP Intake	24	2–10	5	5	23	4–15	7	7
Natomas East Main Drainage Canal	35	6–55	27	27	35	6–35	19	17
Sacramento River at Hood	31	2–12	7	6	31	4–15	8	7
San Joaquin River near Vernalis	28	9–149	69	73	29	12–168	74	78
Channel and diversion stations								
Old River at Station 9	22	12–150	60	46	23	12–54	27	26
Old River at Bacon Island	19	9–153	52	38	21	10–55	24	21
Banks Pumping Plant	21	16–78	45	43	24	15–77	30	29
Contra Costa Pumping Plant	19	10–154	60	53	21	11–98	35	27
Mallard Island	16	7–5,360	1,276	417	17	9–634	160	68

Table 6-3 Summary of salinity during three consecutive sampling periods

Station	Study period	EC (µS/cm)			TDS (mg/L)		
		Range	Average	Median	Range	Average	Median
Sacramento River at Hood	2004–2005	111–240	161	154	69–140	97	93
	2002–2003	114–239	163	160	72–138	100	102
	1999–2001	96–228	158	155	61–137	97	95
San Joaquin River near Vernalis	2004–2005	120–1,170	679	710	75–635	330	347
	2002–2003	352–1,180	748	715	208–654	445	414
	1999–2001	195–1,120	543	549	113–652	315	318
Banks Pumping Plant	2004–2005	196–671	377	350	108–378	218	204
	2002–2003	173–666	407	387	104–409	239	212
	1999–2001	215–725	408	384	123–388	228	220

Chapter 7 Other Water Quality Constituents

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Chapter 7 Other Water Quality Constituents

This chapter summarizes data for constituents with primary and secondary drinking water standards that were not discussed previously in this report, as well as data for pH, alkalinity, hardness, and turbidity during the reporting period. Constituents with primary standards include antimony, arsenic, barium, cadmium, chromium, lead, mercury, nickel, combined nitrate and nitrite, and selenium; constituents with secondary standards are aluminum, boron, copper, iron, manganese, silver, and zinc, These constituents can either be harmful to human health or affect taste, odor, and appearance when present in drinking water above their maximum contaminant levels (MCLs).

MCL = maximum contaminant level

Constituents with Primary Standards

Ten constituents—antimony, arsenic, barium, cadmium, chromium, lead, mercury, nickel, combined nitrate and nitrite, and selenium—are constituents with MCLs that are monitored by Municipal Water Quality Investigations (MWQI) at the H.O. Banks Pumping Plant. These constituents are no longer routinely monitored at other MWQI stations because historical data indicates that they do not appear to affect the quality of Delta source waters. These constituents may adversely affect human health when exposure exceeds their MCLs; however, none of the primary constituents monitored and regulated by federal and State laws were detected at or above their respective MCLs (Table 7-1). Out of the 10 primary regulated constituents, antimony, barium, cadmium, and mercury were not detected. Lead was detected once; however, the concentration was much lower than its MCL. Arsenic, chromium, nickel, combined nitrate and nitrite, and selenium were detected, but the concentrations were never at or above their respective MCLs.

MWQI = Municipal Water Quality Investigations

Table 7-1 Summary of regulated primary constituents

Arsenic was the only regulated constituent monitored at both Banks Pumping Plant and the Natomas East Main Drainage Canal (NEMDC). Common sources of arsenic are erosion of natural deposits, runoff from orchards, and runoff from glass and electronics production wastes (EPA 2003). Although concentrations were low, arsenic was found in all samples collected at NEMDC and was found in 24 of the 25 samples taken at Banks. Even though NEMDC had higher arsenic concentrations compared with the other stations, arsenic loads from NEMDC are not a major concern due to NEMDC's relatively low inflows to Delta source waters.

NEMDC = Natomas East Main Drainage Canal

Constituents with Secondary Standards

Constituents with secondary standards affect taste, odor, and appearance of finished drinking water. Federal secondary drinking water regulations are non-enforceable guidelines, but California secondary standards are enforceable (see Appendix A). Monitoring of these constituents is required for finished drinking water. Historical data indicate that metallic constituents such as aluminum, copper, iron, manganese, silver, and zinc are not a threat to Delta source waters and, therefore, are monitored only at Banks and NEMDC. Out of the 6 secondary constituents, only 2 were reported to have exceeded their MCLs (Table 7-2). Aluminum and manganese were detected at NEMDC, but were not detected at Banks. Aluminum at NEMDC was detected at a high of 0.34 milligrams per liter with a median of 0.04 mg/L. The MCL set by National Secondary Drinking Water Regulations and the California Department of Health Services (DHS) is 0.2 mg/L. The MCL for

Table 7-2 Summary of secondary constituents

mg/L = milligrams per liter

DHS = California Department of Health Services manganese is 0.05 mg/L; however, the maximum value reported for manganese was 0.081 mg/L, with a median of 0.031 mg/L.

Copper, iron, and zinc are 3 constituents that were detected at Banks but never exceeded the MCL. Silver was undetected at both Banks Pumping Plant and NEMDC. Data collected during the reporting period suggest that concentrations of the 6 secondary constituents were seldom above their MCLs.

Boron

Boron is an unregulated contaminant that is required by DHS to be monitored in drinking water. Boron is a naturally occurring inorganic material that leaches into the water from natural deposits (GSWC 2006). DHS established an action level (AL) of 1 mg/L, based on the health advisory levels of contaminants that have no primary MCLs. ALs are not enforceable, but exceeding them in finished drinking water prompts statutory requirements and recommendations by DHS for consumer notices.

GSWC. 2006. 2006 Annual Water Quality Report. .www.aswater.com/CSC/Water_Quality/Water_Quality_Report_2006/water_quality_report_2006.html. (accessed 30 May 2006).

AL = action level

WTP = water treatment plant

Boron at American River at E.A. Fairbairn Water Treatment Plant, Sacramento River at West Sacramento WTP Intake, and Sacramento River at Hood was never detected at or above its reporting limit. Boron analyses at 6 of the other 7 stations never exceeded the DHS-mandated AL. The Mallard Island station exceeded the 1 mg/L AL 2 out of the 23 times it was sampled. At the diversion stations, both Banks and the Contra Costa Pumping Plant remained within the Article 19 specified monthly average of 0.6 mg/L (Table 7-3).

Table 7-3 Summary of boron data at MWQI stations

Ammonia, Nitrate, and Combined Nitrate and Nitrite

Title 22 of the California Code of Regulations (Title 22, Division 4, Chapter 15, Article 4, Section 64432) establishes a 45 mg/L MCL for nitrate (expressed as nitrate), a 10 mg/L MCL for nitrate + nitrite (as N), and a 1 mg/L MCL for nitrite (as N). These chemicals are known to cause adverse heath effects when exposure exceeds recommended MCLs. Both nitrate and nitrite were detected at the Vernalis monitoring station and at NEMDC. Nitrates have a high potential to migrate to groundwater and affect drinking water supplies (EPA 2006). Nitrate and nitrite were detected at all 10 stations, but never exceeding MCLs (Table 7-4).

EPA. 2006. Consumer Factsheet on: Nitrates/ Nitrites. www.epa.gov/safewater/contaminants/dw_contamfs/nitrates.html (accessed 13 June 2006). Feb.

Table 7-4 Summary of ammonia, nitrate and nitrate + nitrite, Oct 2003 through Sep 2005

Ammonia is not a constituent with a primary standard; however, it is a general indicator of the presence of organic waste such as fecal matter (Wilhelm and Maluk 1998). Ammonia results from the biological dissolution of nitrate and is a primary end product of the decomposition of organic matter. Sources of organic nitrates are human sewage, livestock manure, and fertilizers (EPA 2006). Out of the 10 stations, Hood had the highest levels of ammonia (Table 7-4), largely attributed to the discharges from the Sacramento Regional and West Sacramento wastewater treatment plants.

Wilhelm and Maluk. 1998. Fecal-Indicator Bacteria in Surface Waters of the Santee River Basin and Coastal Drainages, North and South Carolina, 1995-98. USGS FS-085-98. Oct. sc.water.usgs.gov/nawqa/pubs/fs-085-98/index.html (accessed 13 June 2006).

pH

The median pH for the 10 stations ranged from 6.4 to 7.2 with a median of 6.8 (Table 7-5). The American River station had the lowest median pH, and the San Joaquin River (SJR) near Vernalis had the highest. Slight increases in pH can result from seawater influence and indirectly from algal photosynthesis in nutrient-rich waters by CO_2 consumption. Optimal pH in

Table 7-5 Summary of pH and alkalinity, Oct 2003 through Sep 2005

SJR = San Joaquin River

drinking water ranges from 6.5 to 8.5, even though no regulations reinforce standards for pH in the water. Accordingly, the pH of Delta source water was within the recommended range of pH for drinking water.

Alkalinity

Alkalinity of water has an acid neutralizing capacity and is the sum of all the titratable bases (Eaton et al. 1995). Alkalinity is a function of dissolved carbonates, bicarbonates, and hydroxides of the water. Alkalinity is of interest to participants in the MWQI Program because the federal Disinfectant and Disinfection Byproduct Rule (EPA 1998) establishes requirements for removal of organic carbon in source waters based on total organic carbon concentrations and alkalinity.

Eaton et al. 1995. Standard methods for the examination of water and wastewater / prepared and published jointly by American Public Health Association, American Water Works Association, Water Environment Federation. 19th ed. Washington, DC: American Public Health Association. P. 2-25 and 2-35

EPA. 1998. Stage 2 Disinfectants and Disinfection Byproducts Rule. www.epa.gov/safewater/disinfection/stage2/index.html. Accessed on May 26, 2006.

Of the 10 monitoring stations, American River at E.A. Fairbairn WTP had the lowest median alkalinity of 25 mg/L as calcium carbonate ($CaCO_3$); while the SJR near Vernalis had the highest median alkalinity of 107 mg/L as $CaCO_3$ (Figure 7-1). The median alkalinity of Sacramento River stations and the Delta channel stations ranged from 60 to 68 mg/L as $CaCO_3$ (see Table 7-5 and Figure 7-1). Median values from the Delta diversion stations and the Mallard Island station ranged from 70 to 72 mg/L as $CaCO_3$ (see Figure 7-1). NEMDC had the second highest median alkalinity of 79 mg/L as $CaCO_3$ (see Table 7-5). The overall alkalinity at the stations ranged from 25 to 107 mg/L as $CaCO_3$; however, the variations were relatively small as indicated by the minor differences between the average and median for each station (see Table 7-5).

$CaCO_3$ = calcium carbonate

Figure 7-1 Alkalinity at seven MWQI stations

Hardness

Total hardness of water is defined as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter (Eaton et al. 1995). Many industrial and domestic water users are concerned about the hardness of their water. Hard water requires more soap and synthetic detergents for home laundry and washing and contributes to scaling in boilers and industrial equipment. Hardness is caused by compounds of calcium and magnesium and by a variety of other metals. General guidelines for classification of waters are: 0 to 60 mg/L as calcium carbonate, soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/L, hard; and more than 180 mg/L, very hard. (USGS 2006)

USGS. 2006. Explanation of Hardness. water.usgs.gov/owq/Explanation.html. Accessed Nov 1, 2006.

Of the locations monitored through the MWQI Program, the lowest hardness was found in the American River water, and the highest was found at Mallard Island, which is heavily influenced by seawater. Excluding the Mallard Island station, hardness for the other stations ranged from 17 to 231 mg/L as $CaCO_3$; the average was from 23 to 128 mg/L as $CaCO_3$ and median hardness was from 23 to 137 mg/L as $CaCO_3$ (Table 7-6 and Figure 7-2). For the 2 diversion stations, hardness ranged from 46 to 175 mg/L as $CaCO_3$, with the average hardness ranging from 86 to 99 mg/L as $CaCO_3$ and the median from 86 to 95 mg/L as $CaCO_3$ (see Table 7-6).

Table 7-6 Summary of hardness and turbidity data, Oct 2003 through Sep 2005

Figure 7-2 Hardness at seven MWQI stations

Turbidity

The turbidity range for all 10 stations ranged from 1 to 124 NTU (see Table 7-6). The American River at E.A. Fairbairn WTP was lowest, having an average and median turbidity of 2 NTU. Stations with the highest turbidity reading and highest median were the SJR near Vernalis and NEMDC.

NTU = nephelometric turbidity unit

Average and median turbidity for Vernalis was 24 and 21 NTU with a high of 124 NTU (see Table 7-6). Average and median turbidity at NEMDC was 36 and 27 NTU with a high of 108 NTU. Average and median turbidity at the 2 diversion stations were from 10 to 14 NTU and from 10 to 11 NTU, respectively.

Because higher turbidity values are associated with heavy runoff, turbidity is generally higher during the wet than the dry months. Turbidity followed this pattern during the 2 water years (Figure 7-3 and Figure 7-4). For the Hood station, turbidity was much higher during the wet months than during the dry months (see Figure 7-4). At Vernalis, in addition to the expected increase in turbidity during the wet months there was also an increase in some of the dry months (see Figure 7-4), probably reflecting returns of valley agricultural drainage to the SJR.

Figure 7-3 Turbidity in the rivers and Delta channels

Figure 7-4 Turbidity at the river and diversion stations

Although both major contributing rivers showed distinct seasonality, seasonality was not apparent at the diversion points. High turbidity observed in waters of both the SJR and Sacramento River during the wet months were not observed at the diversion stations (see Figure 7-4).

Summary

Findings for constituents known to cause adverse effects on human health or consumer acceptance such as taste, odor, and appearance are listed in Table 7-7. Of these primary constituents, antimony, barium, cadmium, and mercury were not detected. The remaining primary constituents were detected, on occasion, but never met or exceeded State or federal MCLs. Secondary constituents, also known to have adverse health effects, were measured and included aluminum and copper. Aluminum was not detected in any samples; copper was detected, but did not meet or exceed State and federal MCLs. Manganese and silver were not detected. The remaining 4 constituents were detected; however, they never exceeded federal or State MCLs.

Table 7-7 Summary of inorganic and miscellaneous constituents

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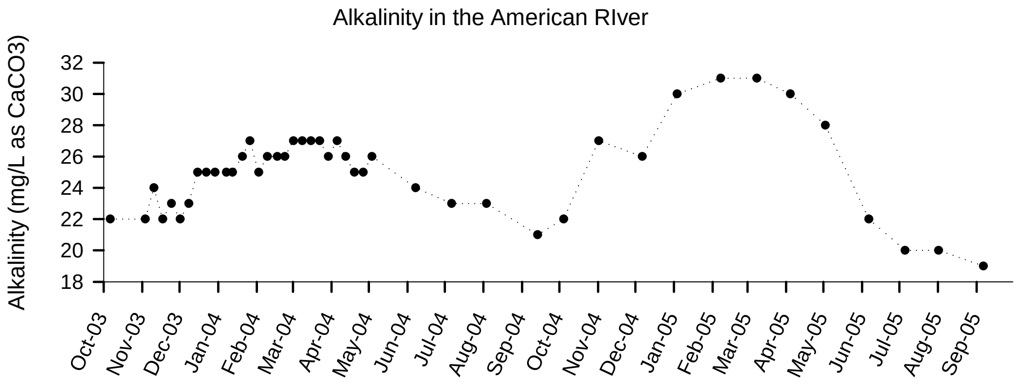
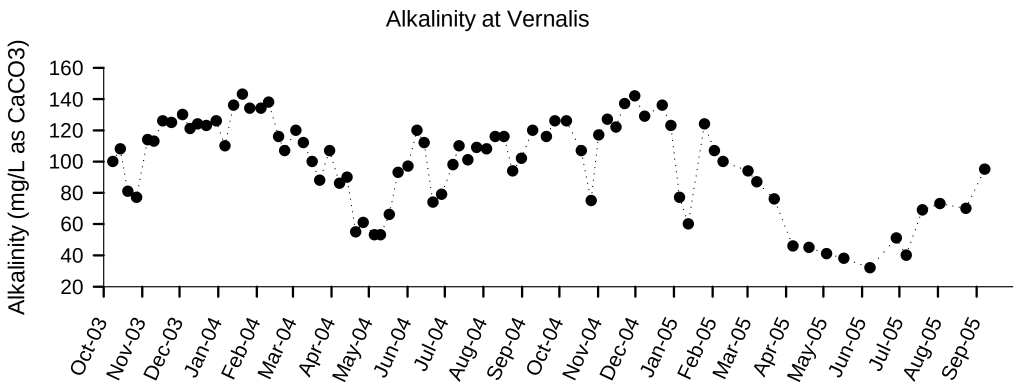
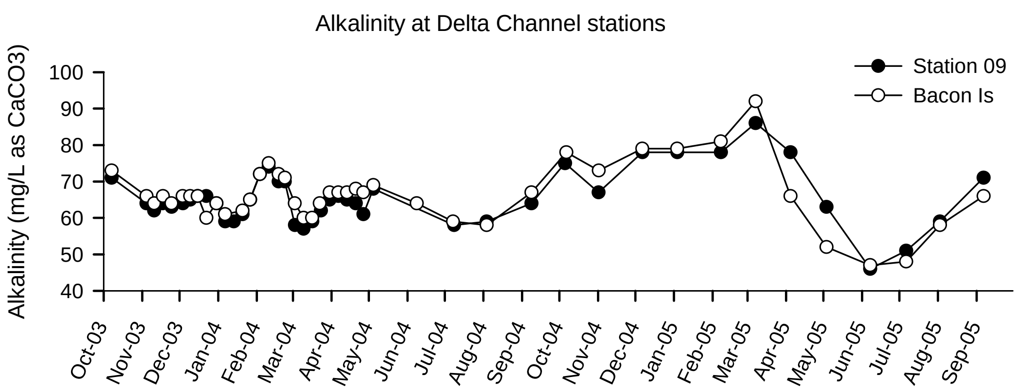
Figure 7-1 Alkalinity at seven MWQI stations







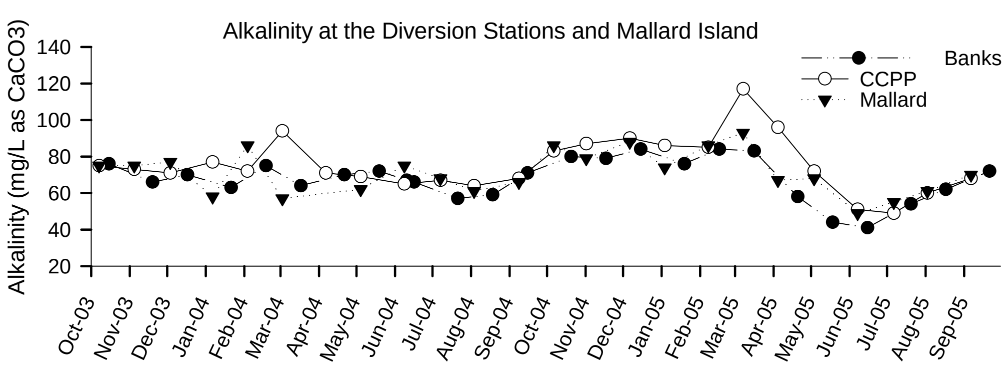


Figure 7-2 Hardness at seven MWQI stations

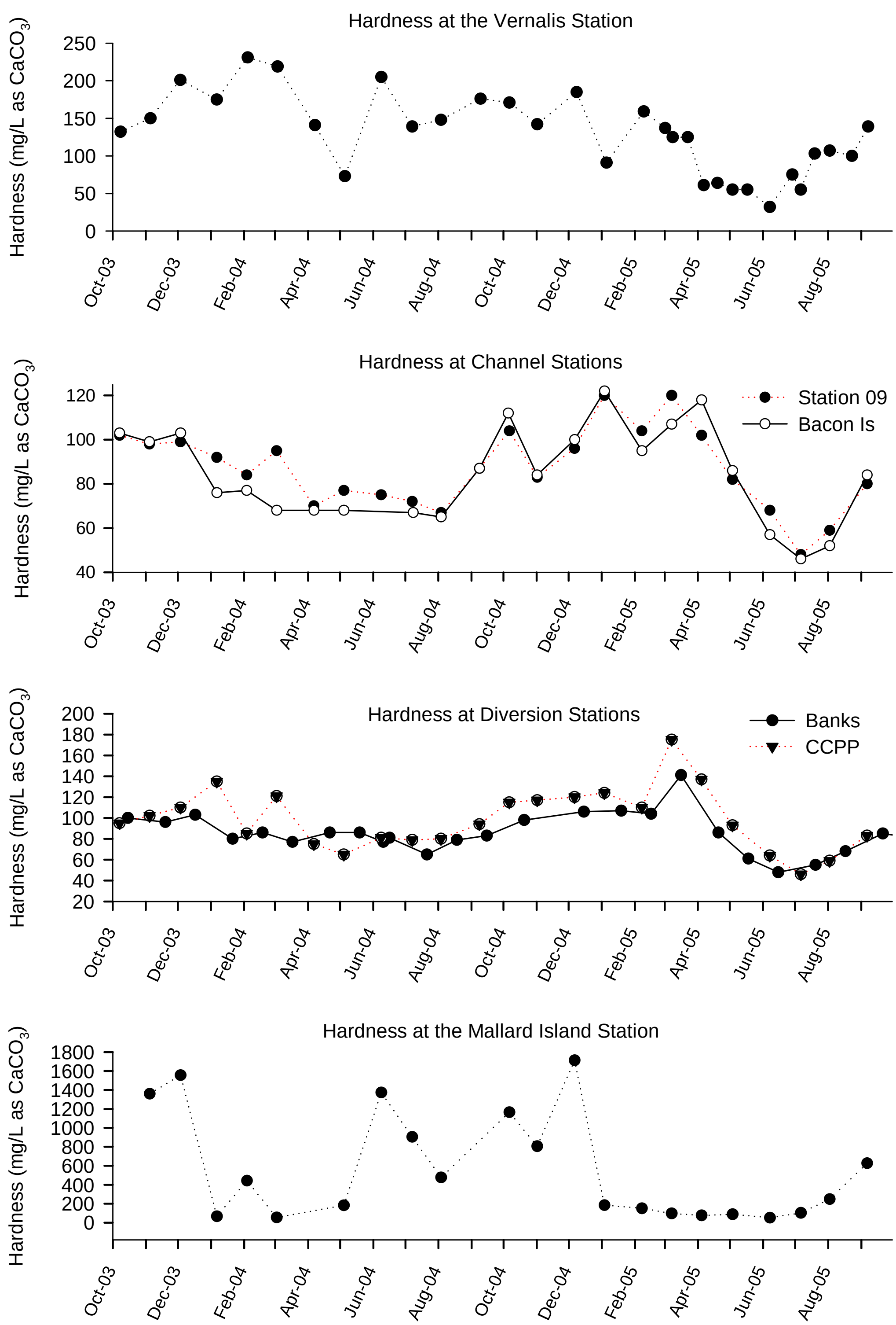


Figure 7-3 Turbidity in the rivers and Delta channels

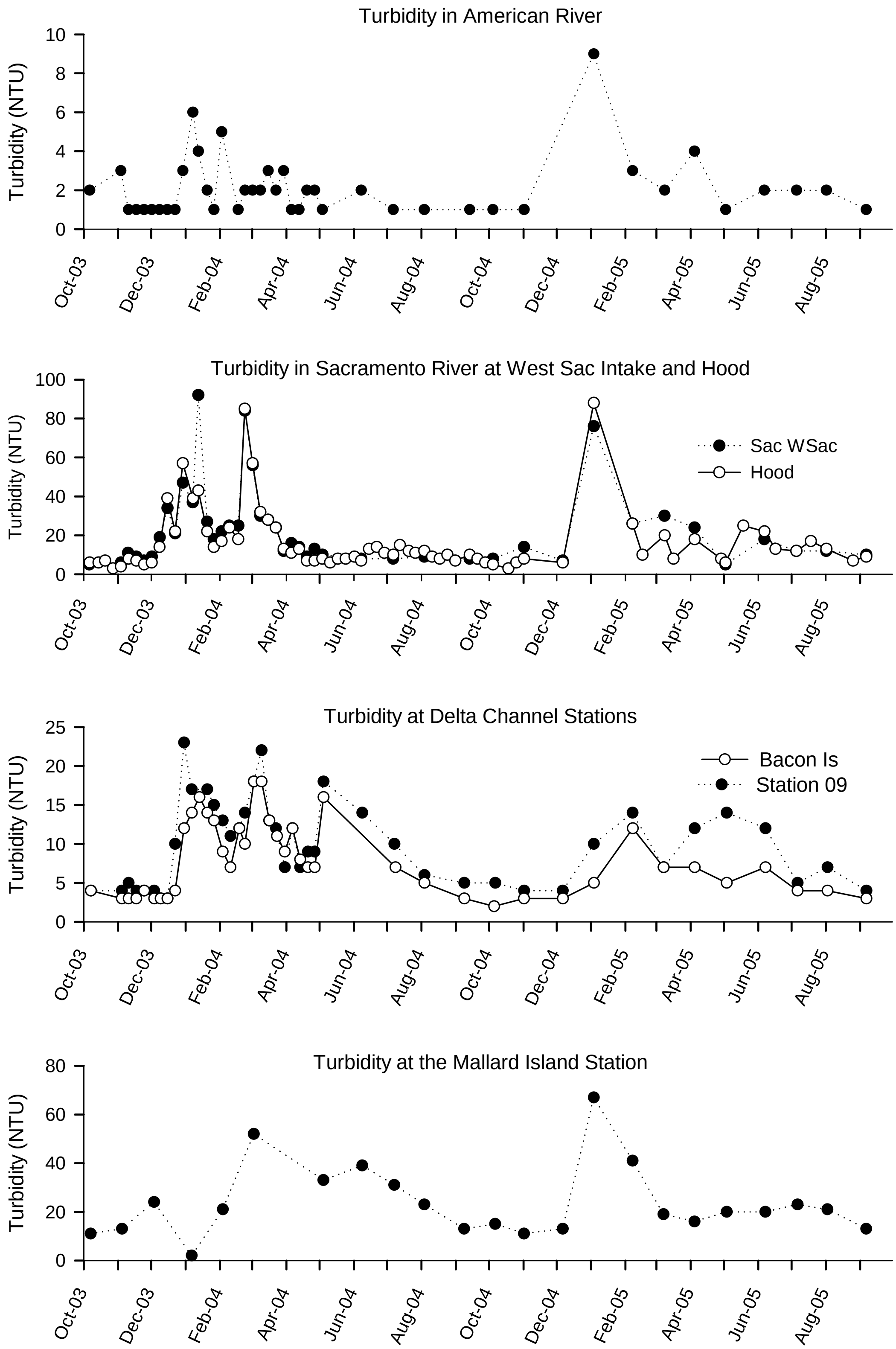


Figure 7-4 Turbidity at the river and diversion stations

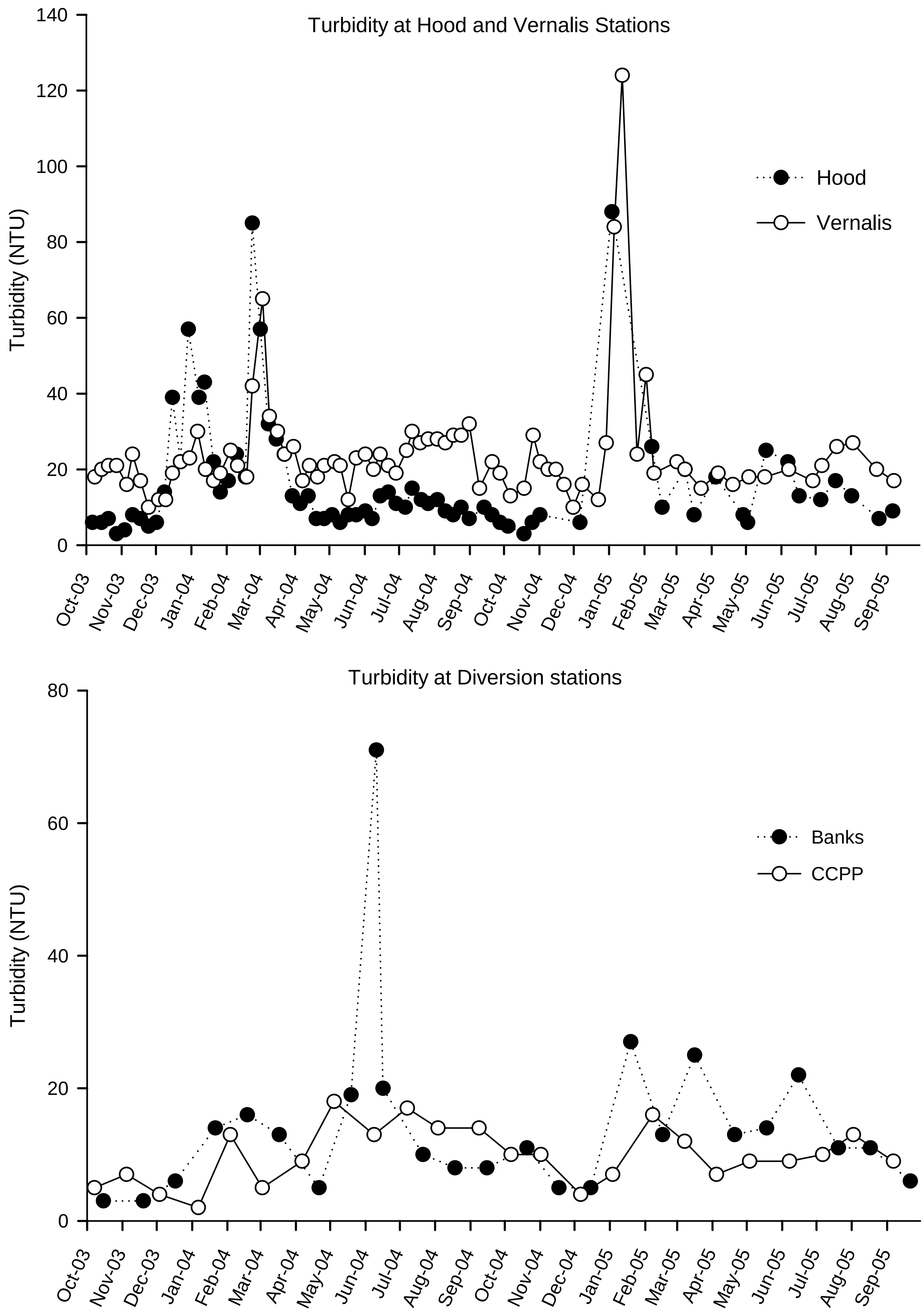


Table 7-1 Summary of regulated primary constituents

Constituents	MCL (mg/L)	Detects/sample number	Range	Median
		Banks		
Antimony	0.006	0/25	–	–
Arsenic	0.01	24/25	0.001–0.003	0.002
Barium	2.0 or 1.0 (DHS)	0/21	–	–
Cadmium	0.005	0/21	–	–
Chromium	0.1 or 0.05 (DHS)	23/25	0.001–0.003	0.002
Lead	0.015	1/25	0.007	0.007
Mercury	0.002	0/25	–	–
Nickel	0.1 (DHS)	22/25	0.001–0.002	0.001
Nitrate + Nitrite	10.0 (DHS)	26/26	0.16-1.50	0.49
Selenium	0.05	14/25	0.001–0.002	0.001
		NEMDC		
Arsenic	0.01	35/35	0.001–0.006	0.003

Table 7-2 Summary of secondary constituents

	Banks (mg/L)				NEMDC (mg/L)			
Constituents	MCL	Detects/sample number	Range	Median	MCL	Detects/sample number	Range	Median
Aluminum	0.2	0/21	–	–	0.2	31/35	0.01–0.34	0.04
Copper	1.0	24/25	0.001–0.005	0.002	1.0	35/35	0.002–0.004	0.003
Iron	0.3	18/25	0.005–0.075	0.018	0.3	35/35	0.021–0.299	0.087
Manganese	0.05	–	–	–	0.05	35/35	0.006–0.081	0.031
Silver	0.1	0/21	–	–	0.1	–	–	–
Zinc	5.0	1/25	0.006	0.006	5.0	–	–	–

Table 7-3 Summary of boron data at MWQI stations[a]

Station	Positive detects/ sample number	Range	Average	Median
		---------------------mg/L---------------		
Stations north of the Delta				
American River at E.A. Fairbairn WTP	0/24	–	–	–
West Sacramento WTP Intake	0/24	–	–	–
Natomas East Main Drainage Canal	19/35	0.1 –0.2	0.1	0.1
Sacramento River at Hood	0/31	–	–	–
San Joaquin River near Vernalis	26/31	0.1–0.6	0.3	0.3
Channel and diversion stations				
Old River at Station 9	12/24	0.1–0.2	0.1	0.1
Old River at Bacon Island	6/23	0.1–0.2	0.1	0.1
Banks Pumping Plant	17/25	0.1–0.4	0.1	0.1
Contra Costa Pumping Plant	17/24	0.1–0.3	0.2	0.2
Mallard Island	17/23	0.1–1.3	0.5	0.4

a. Boron is currently an unregulated constituent that requires monitoring.

Table 7-4 Summary of ammonia, nitrate and nitrate + nitrite, Oct 2003 through Sep 2005

	Ammonia (mg N/L)			Nitrate (mg NO_3/L)			Nitrate + Nitrite (mg N/L)		
Station	Sample number	Range	Median	Sample number	Range	Median	Sample number	Range	Median
Stations north of the Delta									
American River at E.A. Fairbairn WTP	10	0.01–0.06	0.03	18	0.1–1.3	0.3	23	0.01–0.36	0.06
West Sacramento WTP Intake	11	0.01–0.03	0.02	27	0.2–4.2	0.5	27	0.05–0.40	0.12
Natomas East Main Drainage Canal	38	0.02–0.32	0.06	41	1.5–16.1	4.8	39	0.37–3.81	1.05
Sacramento River at Hood	35	0.08–0.84	0.30	36	0.2–2.3	0.6	35	0.07–0.60	0.13
San Joaquin River near Vernalis	18	0.01–0.32	0.04	37	1.0–10.8	6.9	35	0.18–2.76	1.60
Channel and diversion stations									
Old River at Station 9	27	0.01–0.18	0.04	27	0.6–5.6	2.0	27	0.15–1.30	0.44
Old River at Bacon Island	23	0.01–0.09	0.03	26	0.1–4.1	1.6	26	0.03–0.92	0.34
Banks Pumping Plant	27	0.02–0.15	0.05	27	0.5–6.9	2.0	26	0.16–1.50	0.49
Contra Costa Pumping Plant	16	0.01–0.08	0.02	19	0.2–5.7	1.2	22	0.02–1.20	0.21
Mallard Island	26	0.04–0.21	0.08	21	1.0–2.2	1.6	26	0.21–0.51	0.36

Table 7-5 Summary of pH and alkalinity, Oct 2003 through Sep 2005

	pH			Alkalinity (mg/L as $CaCO_3$)			
Station	Number of samples	Range	Median	Number of samples	Range	Average	Median
Stations north of the Delta							
American River at E.A. Fairbairn WTP	44	5.7–6.8	6.4	44	19–31	25	25
West Sacramento WTP Intake	44	6.1–7.6	6.8	44	51–99	70	68
Natomas East Main Drainage Canal	35	6.2–7.8	7.0	35	28–170	82	79
Sacramento River at Hood	72	5.5–7.6	6.6	72	47–91	63	60
San Joaquin River near Vernalis	81	5.8–8.8	7.2	81	32–143	99	107
Channel and diversion stations							
Old River at Station 9	43	6.4–7.5	6.8	43	47–92	66	66
Old River at Bacon Island	43	6.3–8.2	7.0	43	46–86	65	64
Banks Pumping Plant	25	6.4–8.0	6.7	25	41–84	68	70
Contra Costa Pumping Plant	24	6.5–7.9	7.0	24	49–117	75	72
Mallard Island	23	6.3–7.5	6.8	23	49–93	71	70

Table 7-6 Summary of hardness and turbidity data, Oct 2003 through Sep 2005

Station	Hardness (mg/L as $CaCO_3$)				Turbidity (NTU)			
	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
Stations north of the Delta								
American River at E.A. Fairbairn WTP	23	17–30	23	23	42	1–9	2	2
West Sacramento WTP Intake	23	46–93	63	59	44	5–92	22	15
Natomas East Main Drainage Canal	34	26–158	83	78	36	6–108	36	27
Sacramento River at Hood	29	46–92	59	55	72	3–88	16	11
San Joaquin River near Vernalis	31	32–231	128	137	81	10–124	24	21
Channel and diversion stations								
Old River at Station 9	24	48–120	87	86	43	3–23	10	10
Old River at Bacon Island	23	46–122	85	84	43	2–18	8	17
Banks Pumping Plant	26	48–141	86	86	25	3–71	14	11
Contra Costa Pumping Plant	24	46–175	99	95	24	2–18	10	10
Mallard Island	21	52–1712	559	248	23	2–67	24	20

Table 7-7 Summary of inorganic and miscellaneous constituents

Constituents	Findings	Regulation compliance
Constituents with adverse effects on human health		
Aluminum	Never detected	Never exceeded State or federal MCL of 0.2 mg/L
Antimony, barium, cadmium and mercury	Never detected	Never exceeded federal primary MCL
Lead	Detected in 1 out of 25 samples Value: 0.007	Never exceeded federal primary MCL
Arsenic	Detected in 24 out of 25 samples; range: 0.001–0.003 mg/L; median: 0.002 mg/L	Never exceeded federal MCL of 0.01 mg/L
Chromium (total)	Detected in 23 out of 25 samples; range: 0.001–0.003 mg/L; median: 0.002 mg/L	Never exceeded federal MCL of 0.1 mg/L or State MCL of 0.05 mg/L
Copper	Detected in 24 out of 25 samples; range: 0.001–0.005 mg/L; median: 0.002 mg/L	Never exceeded State or federal MCL of 1.0 mg/L
Nickel	Detected in 22 of 25 samples; range: 0.001–0.002 mg/L; median: 0.001 mg/L	Never exceeded State MCL of 0.1 mg/L
Nitrate+Nitrite (as N)	Detected in all 26 samples; range: 0.16–1.50 mg/L; median: 0.49 mg/L	Never exceeded State MCL of 10 mg/L
Selenium	Detected in 14 of 25 samples; range: 0.001–0.002 mg/L; median: 0.001mg/L	Never exceeded federal MCL of 0.05 mg/L
Constituents with adverse effects on taste, odor, or appearance		
Iron	Detected in 18 of 25 samples; range: 0.005–0.075 mg/L; median: 0.018 mg/L	Never exceeded federal MCL of 0.3 mg/L
Manganese and silver	Never detected	Never exceeded federal secondary MCL
Zinc	Detected in 1 out of 25 samples; Value: 0.006	Never exceeded federal MCL of 5 mg/L

MCL = maximum contaminant level

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Overview

This data quality review covers the reporting period from October 1, 2003, through September 30, 2005. Data from 10 stations were collected through the Municipal Water Quality Investigations (MWQI) Program during this reporting period.

MWQI = Municipal Water Quality Investigations

The data review was performed using the available quality control (QC) data stored in the California Department of Water Resources' (DWR) Field and Laboratory Information Management System (FLIMS) database. This database was used to retrieve the data and flag the analyses that were outside established control limits.

QC = quality control

DWR = California Department of Water Resources

FLIMS = Field and Laboratory Information Management System

The data quality review indicated that the 2003–2005 MWQI project data were of acceptable quality overall. A few analyses were outside the control limits, but they were not considered to have a significant impact on the overall data quality of the project. There was a data collection error on July 6, 2004 at 4 of the stations. The reported measurements for electrical conductivity (EC) and total dissolved solids (TDS) were erroneous; therefore, field EC was used instead. TDS was then calculated based on the EC values. This error did not significantly impact the data report but should be noted when reviewing the data. The results of the review are presented below.

EC = electrical conductivity

TDS = total dissolved solids

Field Procedures Quality Control

Field Duplicates

Field duplicates are replicate samples taken at a randomly selected station during each field run to evaluate precision of field and laboratory procedures. The results of field duplicate analyses are evaluated by calculating relative percent differences (RPDs) and comparing the RPDs with established control limits. The equation for expressing precision is:

RPDs = relative percent differences

$$RPD= (D1 -D2)/[(D1+D2)/2] \times 100,$$

where D1 is the first sample value and D2 is the second sample value. During the study period, 1,634 field duplicate analyses were performed and 60 (3.7%) of the RPDs exceeded the acceptable control limits (Table 8-1). These duplicate results indicate that field and laboratory procedures were of acceptable precision for the project.

Table 8-1. Field Duplicates

Field Blanks

Field blanks monitor contamination originating from the collection, transport, and storage of environmental samples. Filtered blanks help check for contamination from field sample processing procedures. Unfiltered blanks check for contamination from containers and preservatives. In the study period, 1,008 field blank analyses were performed, and 41 (4.1%) field blanks exceeded the control limit (Table 8-2).

Table 8-2. Field Blanks

Internal Quality Controls

Internal QCs are performed by the laboratory to control the accuracy and precision of the measurement process and determine whether the lab operations are within acceptable QC limits. Environmental samples are grouped in "batches," with approximately 20 samples per batch. Generally, one of each QC measures such as method blank, matrix spike, etc. is performed with each batch to confirm that the analytical method is in control. In some cases the laboratory performs more than one of each of the QC measures to ensure the quality of the batch. The total number of internal QC analyses performed per analyte is shown in Table 8-3. The following is a review of the internal QC for the project.

Table 8-3. Total internal QC batches grouped by analyte

Sample Holding Times

Holding time is the period during which a sample can be stored after collection and preservation without significantly affecting the accuracy of its analysis. During the 2003-2005 study period, there were 6 reported analyses that exceeded the holding time limit. The analytes that exceeded holding time limits were orthophosphate and turbidity. Table 8-4 shows the number of hours or days that the samples were held by the laboratory compared to their holding time limits. The analytes in the table exceeded holding time limits by several hours, and the results of the specific analyses should be interpreted with caution.

Table 8-4. Holding times

Method Blanks

Method blanks are analyzed with every sample set and are used to determine the level of contamination that exists in the analytical procedure. A total of 2,905 method blanks were performed from October 2003 through September 2005, and 19 (0.6%) exceeded the control limits.

The analytes with method blank contamination are shown in Table 8-5. Elimination of blank contamination is more difficult for some analytical methods; therefore, each method has its own specific level of acceptance. Table 8-6 shows the frequency of method blank contamination for these analytes, but the frequency of method blank contamination was low for all the analytes in question.

Table 8-5. Method blank exceedances

Table 8-6. Number of batches with method blank exceedances

Laboratory Control Samples and Duplicates

Laboratory control sample (LCS) recoveries are analyzed to verify that the analytical method is in control. The LCS is a standard made from a different source than the calibration standard and spiked into blank water. The LCS is then analyzed, and the results are compared to the laboratory's control limits. During the period of October 2003 through September 2005, 4,793 LCS analyses were performed, and 6 LCSs exceeded the control limits (Table 8-7). The frequency with which the LCS was outside the control limits was very low (Table 8-8), but whenever the results fall outside the control limits, sample results are deemed unacceptable. Once it is corrected and the LCS is within limits, the samples are reanalyzed.

LCS = laboratory control sample

Table 8-7. LCS recovery exceedances

Table 8-8. Frequency of QC batches with LCS recovery exceedances

Matrix Spike Recovery

Matrix spike recoveries are used to describe the precision and accuracy of an analytical measurement. The results of matrix spike recoveries indicate the accuracy of analysis given the interference peculiar to a given matrix. Matrix spikes are prepared by adding a known concentration of analyte to an environmental sample with known background concentration. The percent recovery must fall within acceptable limits. During the study period, 7,311 matrix spike recoveries were performed, and 30 (0.4%) exceeded the control limits. The batches with matrix spike recoveries outside the control limits are shown in Table 8-9. The analytes that had matrix spike exceedances were chloride, Kjeldahl nitrogen, phosphorus, and sulfate. Phosphorus had a frequency of exceedance of 7.6% and Kjeldahl nitrogen 11.6% (Table 8-10). Some of the recoveries were high, but the RPDs and LCSs for those batches were within limits; therefore, the batch is considered in control. Recoveries that were lower than the control limits can be attributed to matrix interference, but the LCS for those batches were in control.

Table 8-9. Matrix spike recovery exceedances

Table 8-10. Frequency of QC batches with matrix spike recovery exceedances

Matrix Spike Duplicates

Matrix spike duplicate results indicate the precision of the analytical method in a given matrix. The difference between the duplicate samples is reported as an RPD. This difference is compared against the laboratory's control limits as a conservative approach to determining precision. During the study period, 3,569 matrix spike duplicates were performed. Only 9 matrix spike duplicate batches exceeded the control limits (0.25%), shown in Table 8-11. The analytes were Kjeldahl nitrogen and phosphorus, and the frequency of exceedance is shown in Table 8-12. These analytes were out of recovery limits for the matrix spikes as well as the spike duplicates, which suggests matrix interference. The LCS recoveries are within limits for these analytes; therefore, the batch is considered in control.

Table 8-11. Matrix spike duplicate recovery exceedances

Table 8-12. Number of matrix spike duplicate recovery exceedances

Chapter 8 Data Quality Control

Tables

Table 8-1 Field Duplicates

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	Units	RPD	RPD Limit
Conductance (EC)	12/29/2003	CB1203B1210	CB1203B1211	188	152	µS/cm	21.18%	15
Conductance (EC)	7/6/2004	CA0704B0217	CA0704B0221	652	188	µS/cm	110.48%	15
Dissolved ammonia	1/6/2004	CB0104B1285	CB0104B1287	0.02	0.01	mg/L as N	66.67%	20
Dissolved ammonia	6/7/2005	CA0605B0360	CA0605B0365	0.02	0.01	mg/L as N	66.67%	20
Dissolved ammonia	2/2/2004	CA0204B0046	CA0204B0050	0.03	0.02	mg/L as N	40.00%	20
Dissolved bromide	2/18/2004	CA0204B0083	CA0204B0086	0.06	0.04	mg/L	40.00%	20
Dissolved bromide	3/9/2004	CB0304B0065	CB0304B0068	0.03	0.04	mg/L	28.57%	20
Dissolved bromide	4/20/2004	CB0404B0188	CB0404B0191	0.03	0.02	mg/L	40.00%	20
Dissolved bromide	4/26/2004	CB0404B0199	CB0404B0202	0.04	0.02	mg/L	66.67%	20
Dissolved bromide	10/14/2003	CC1003B0797	CC1003B0798	0.02	0.01	mg/L	66.67%	20
Dissolved nitrate	10/4/2004	CA1004B0824	CA1004B0828	0.3	0.4	mg/L	28.57%	20
Dissolved nitrite + nitrate	6/6/2005	CA0605B0350	CA0605B0353	0.03	0.02	mg/L as N	40.00%	20
Dissolved rrganic carbon	12/22/2004	CA1204B1520	CA1204B1521	5.5	3.6	mg/L as C	41.76%	30
pH	3/8/2005	CA0305B0187	CA0305B0192	6.8	7.5	pH units	9.79%	3
pH	7/20/2004	CA0704B0271	CA0704B0272	6.2	6.4	pH units	3.17%	3
pH	11/15/2004	CA1104B1251	CA1104B1253	7.2	6.9	pH units	4.26%	3
pH	12/22/2003	CB1203B1151	CB1203B1154	8	7.3	pH units	9.15%	3
Total dissolved solids	7/6/2004	CA0704B0217	CA0704B0221	370	107	mg/L	110.27%	15
Total Kjeldahl nitrogen	11/4/2003	CU1103B0820	CU1103B0822	0.2	0.3	mg/L as N	40.00%	25
Total Kjeldahl nitrogen	6/8/2004	CA0604B0123	CA0604B0127	0.3	0.4	mg/L as N	28.57%	25
Total Kjeldahl nitrogen	9/8/2004	CA0904B0692	CA0904B0694	0.3	0.4	mg/L as N	28.57%	25
Total Kjeldahl nitrogen	12/6/2004	CA1204B1369	CA1204B1372	0.4	0.3	mg/L as N	28.57%	25
Total Kjeldahl nitrogen	1/3/2005	CB0105B0001	CB0105B0005	0.6	0.8	mg/L as N	28.57%	25
Total Kjeldahl nitrogen	6/7/2005	CA0605B0360	CA0605B0365	0.5	0.2	mg/L as N	85.71%	25
Total Kjeldahl nitrogen	8/2/2005	CA0805B0542	CA0805B0545	0.2	0.3	mg/L as N	40.00%	25
Total Kjeldahl nitrogen	9/6/2005	CA0905B0635	CA0905B0639	0.3	0.2	mg/L as N	40.00%	25
Total Kjeldahl nitrogen	2/2/2004	CA0204B0046	CA0204B0050	0.3	0.4	mg/L as N	28.57%	25
Total Kjeldahl nitrogen	10/4/2004	CA1004B0824	CA1004B0828	0.2	0.1	mg/L as N	66.67%	25

Table 8-1 continues on next page

Table 8-1 continued

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	Units	RPD	RPD Limit
Total Kjeldahl nitrogen	1/3/2005	CB0105B0010	CB0105B0014	1.3	0.5	mg/L as N	88.89%	25
Total Kjeldahl nitrogen	2/7/2005	CA0205B0098	CA0205B0102	0.2	0.3	mg/L as N	40.00%	25
Total Kjeldahl nitrogen	8/1/2005	CA0805B0532	CA0805B0533	0.6	0.8	mg/L as N	28.57%	25
Total organic carbon	9/6/2005	CA0905B0625	CA0905B0626	1.8	1.2	mg/L as C	40.00%	30
Total phosphorus	1/3/2005	CB0105B0001	CB0105B0005	0.08	0.06	mg/L	28.57%	25
Total phosphorus	6/7/2005	CA0605B0360	CA0605B0365	0.16	0.08	mg/L	66.67%	25
Total phosphorus	5/3/2004	CA0504B0065	CA0504B0069	0.06	0.12	mg/L	66.67%	25
Total phosphorus	11/1/2004	CA1104B1004	CA1104B1008	0.08	0.06	mg/L	28.57%	25
Total phosphorus	12/6/2004	CA1204B1359	CA1204B1363	0.1	0.04	mg/L	85.71%	25
Total phosphorus	4/4/2005	CA0405B0244	CA0405B0245	0.08	0.06	mg/L	28.57%	25
Turbidity	11/24/2003	CB1103B1056	CB1103B1058	3	4	NTU	28.57%	15
Turbidity	12/3/2003	CB1203B1090	CB1203B1094	2	4	NTU	66.67%	15
Turbidity	4/26/2004	CB0404B0199	CB0404B0202	6	7	NTU	15.38%	15
Turbidity	7/6/2005	CA0705B0464	CA0705B0467	3	4	NTU	28.57%	15
Turbidity	9/6/2005	CA0905B0635	CA0905B0639	5	4	NTU	22.22%	15
Turbidity	10/27/2003	CC1003B0828	CC1003B0829	4	3	NTU	28.57%	15
Turbidity	5/10/2004	CA0504B0088	CA0504B0090	26	21	NTU	21.28%	15
Turbidity	8/24/2004	CA0804B0566	CA0804B0567	8	10	NTU	22.22%	15
Turbidity	11/30/2004	CA1204B1353	CA1204B1354	12	10	NTU	18.18%	15
Turbidity	12/29/2003	CB1203B1210	CB1203B1211	47	57	NTU	19.23%	15
Turbidity	1/20/2004	CB0104B1308	CB0104B1310	1	2	NTU	66.67%	15
Turbidity	1/26/2004	CB0104B1342	CB0104B1344	2	1	NTU	66.67%	15
Turbidity	3/15/2004	CB0304B0072	CB0304B0073	19	28	NTU	38.30%	15
Turbidity	3/22/2004	CB0304B0090	CB0304B0092	1	2	NTU	66.67%	15
Turbidity	3/29/2004	CA0304B0042	CA0304B0043	10	13	NTU	26.09%	15
Turbidity	4/19/2004	CB0404B0184	CB0404B0186	1	2	NTU	66.67%	15
Turbidity	4/4/2005	CA0405B0244	CA0405B0245	21	18	NTU	15.38%	15
Turbidity	6/6/2005	CA0605B0350	CA0605B0353	1	2	NTU	66.67%	15
Turbidity	9/6/2005	CA0905B0625	CA0905B0626	7	9	v	25.00%	15

Table 8-1 continues on next page

Table 8-1 continued

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	Units	RPD	RPD Limit
UV Absorbance @254nm	10/7/2003	CC1003B0785	CC1003B0787	0.066	0.102	absorbance/cm	42.86%	10
UV Absorbance @254nm	11/3/2003	CU1103B0810	CU1103B0813	0.051	0.058	absorbance/cm	12.84%	10
UV Absorbance @254nm	1/3/2005	CB0105B0010	CB0105B0014	0.194	0.158	absorbance/cm	20.45%	10

NTU = nephelometric turbidity unit(s)

Table 8-2 Field Blanks

Analyte	Collection date	Sample number	Result	Reporting limit	Units
Dissolved ammonia	1/7/2004	CB0104B1275	0.02	0.01	mg/L as N
Dissolved iron	1/19/2005	DA0105B0006	0.01	0.005	mg/L
Dissolved organic carbon	12/2/2003	CB1203B1227	0.5	0.100000001	mg/L as C
Dissolved organic carbon	12/2/2003	CB1203B1228	0.2	0.100000001	mg/L as C
Dissolved organic carbon	12/2/2003	CB1203B1229	0.2	0.100000001	mg/L as C
Dissolved organic carbon	12/2/2003	CB1203B1230	0.2	0.100000001	mg/L as C
Dissolved organic carbon	12/2/2003	CB1203B1231	0.2	0.100000001	mg/L as C
Dissolved organic carbon	1/15/2004	CA0104B0015	0.4	0.100000001	mg/L as C
Dissolved organic carbon	1/15/2004	CA0104B0014	3.2	0.100000001	mg/L as C
Dissolved organic carbon	1/15/2004	CA0104B0026	0.3	0.100000001	mg/L as C
Dissolved organic carbon	1/15/2004	CA0104B0025	0.3	0.100000001	mg/L as C
Dissolved organic carbon	1/15/2004	CA0104B0024	1.7	0.100000001	mg/L as C
Dissolved organic carbon	1/15/2004	CA0104B0016	0.3	0.100000001	mg/L as C
Dissolved organic carbon	11/5/2004	CA1104B1166	0.2	0.100000001	mg/L as C
Dissolved organic carbon	12/8/2004	CA1204B14519	0.2	0.100000001	mg/L as C
Dissolved orthophosphate	6/7/2004	CA0604B0122	0.06	0.01	mg/L as P
Dissolved orthophosphate	1/3/2005	CB0105B0019	0.02	0.01	mg/L as P
Dissolved orthophosphate	1/3/2005	CB0105B0009	0.02	0.01	mg/L as P
Orthophosphate	1/6/2004	CB0104B1293	0.04	0.01	mg/L as P
Total copper	8/17/2005	DA0805B1241	0.002	0.001	mg/L
Total Kjeldahl nitrogen	6/7/2005	CA0605B0368	0.2	0.100000001	mg/L as N
Total organic carbon	1/15/2004	CA0104B0022	0.1	0.100000001	mg/L as C
Total organic carbon	1/15/2004	CA0104B0013	0.1	0.100000001	mg/L as C
Total organic carbon	1/15/2004	CA0104B0023	0.2	0.100000001	mg/L as C
Total organic carbon	11/5/2004	CA1104B1164	0.2	0.100000001	mg/L as C
Total organic carbon	11/5/2004	CA1104B1165	0.1	0.100000001	mg/L as C
Total organic carbon	12/8/2004	CA1204B14518	0.2	0.100000001	mg/L as C
Total phosphorus	11/3/2003	CU1103B0819	0.01	0.01	mg/L
Total phosphorus	11/5/2003	CU1103B0828	0.01	0.01	mg/L
Total phosphorus	12/1/2003	CB1203B1089	0.01	0.01	mg/L
Total phosphorus	1/6/2004	CB0104B1293	0.04	0.01	mg/L
Total phosphorus	2/2/2004	CA0204B0055	0.01	0.01	mg/L
Total phosphorus	2/3/2004	CA0204B0064	0.01	0.01	mg/L
Total phosphorus	3/1/2004	CB0304B0048	0.04	0.01	mg/L
Total phosphorus	3/2/2004	CB0304B0057	0.01	0.01	mg/L
Total phosphorus	4/5/2004	CB0404B0164	0.04	0.01	mg/L
Total phosphorus	4/6/2004	CB0404B0173	0.01	0.01	mg/L
Total phosphorus	6/7/2004	CA0604B0122	0.03	0.01	mg/L
Total phosphorus	1/3/2005	CB0105B0009	0.01	0.01	mg/L
Total phosphorus	5/2/2005	CB0505B0089	0.01	0.01	mg/L
Total phosphorus	6/7/2005	CA0605B0368	0.02	0.01	mg/L

Table 8-3 Total internal QC batches grouped by analyte

Analyte	Method	LCS recovery	RPD-LCS duplicate	Matrix spike	RPD- Matrix spike duplicate	Method blank	RPD sample duplicate
Minor elements							
Alkalinity	Std Method 2320 B	226	113	318	158	114	
Aluminum	ICP/MS trace elements (dissolved)	96	48	190	90	48	
Antimony	ICP/MS trace elements (dissolved)	72	36	134	61	36	
Arsenic	ICP/MS trace elements (dissolved)	96	48	200	94	48	
Barium	ICP/MS trace elements (dissolved)	92	46	163	77	46	
Boron	ICP/MS trace elements (dissolved)	12	6			7	
Cadmium	ICP/MS trace elements (dissolved)	78	39	142	67	39	
Chromium	ICP/MS trace elements (dissolved)	84	42	164	76	42	
Copper	ICP/MS trace elements (dissolved)	96	48	198	91	48	
Iron	ICP/MS trace elements (dissolved)	96	48	198	92	48	
Lead	ICP/MS trace elements (dissolved)	86	43	162	74	43	
Manganese	ICP/MS trace elements (dissolved)	96	48	198	92	48	
Mercury	ICP/MS trace elements (dissolved)					2	
Nickel	ICP/MS trace elements (dissolved)	76	38	144	66	38	
pH	pH - Std Method 2320 B					114	6
Selenium	ICP/MS trace elements (dissolved)	94	47	168	77	47	
Silver	ICP/MS trace elements (dissolved)	78	39	152	72	39	
Turbidity	EPA 180.1	258	127			243	191
Zinc	ICP/MS trace elements (dissolved)	82	41	160	74	41	
Bromide							
Bromide	EPA 300.0 28d Hold	280	140	700	349	122	
Organic Carbon and UVA							
Dissolved Organic Carbon (DOC)	EPA 415.1 (D) Ox	292	146			146	
Total Organic Carbon (TOC)	EPA 415.1 (T) Ox	296	146			148	
Total Organic Carbon (TOC)	EPA 415_1 (T) Cmbst	226	111			113	
Organic Carbon (dissolved) by combustion	EPA 415.1 (D) Cmbst	214	106			107	
UV Absorbance @254nm	Std Method 5910B	192	116			234	274

Table 8-3 continued on next page

Table 8-3 continued

Analyte	Method	LCS recovery	RPD-LCS duplicate	Matrix spike	RPD- Matrix spike duplicate	Method blank	RPD sample duplicate
Salinity							
Conductance (EC)	Std Method 2510-B					117	115
Chloride	EPA 300.0 28d Hold	280	140	1076	539	121	
Sulfate	EPA 300.0 28d Hold	276	137	1004	502	118	
Total Dissolved Solids (TDS)	Std Method 2540-C					86	
Hardness	Std Method 2340 B						
Nutrients							
Nitrate	EPA 300.0 28d Hold	236	118	644	322	101	
Nitrate	EPA 300.0 48 hr (N03, OP)	30	15	68	32	13	
Nitrite+Nitrate	Std Method 4500-NO3-F modified	164	82	294	147	80	
Ammonia	EPA 350.1	164	82	298	149	80	
Kjeldahl Nitrogen	EPA 351.2	148	74	120	60	73	
Orthophosphate	EPA 365.1 (DWR modified)	136	68	256	128	67	
Orthophosphate	Std Method 4500-P, F	28	14	16	8	13	
Phosphorus	EPA 365.4	113	75	144	72	75	
Totals		4,793	2427	7311	3569	2905	586

Table 8-4 Holding times

Analyte	Sample number	Holding time	Limit
Ortho-phosphate (dissolved)	CA1203B0001	169 hours	48
Ortho-phosphate (dissolved)	CU1103B0812	49 hours	48
Turbidity	DA0405B1037	51 hours	48
Turbidity	DA0405B1039	50 hours	48
Turbidity	DA0705B1187	54 hours	48
Turbidity	DA0705B1188	51 hours	48

Table 8-5 Method blank exceedances

Analyte	Method	Batch number	Result	Reporting limit	Units
Alkalinity	Std Method 2320 B	BL04B17769	5.4	1.0	mg/L as $CaCO_3$
Alkalinity	Std Method 2320 B	BL04B16607	5	1.0	mg/L as $CaCO_3$
Conductance (EC)	Std Method 2510-B	BL04B17707	6.6	1.0	µS/cm
Kjeldahl nitrogen	EPA 351.2	BL05B20060	0.2	0.1	mg/L as N
Kjeldahl nitrogen	EPA 351.3	BL05B20155	0.2	0.1	mg/L as N
Kjeldahl nitrogen	EPA 351.4	BL05B20391	0.2	0.1	mg/L as N
Kjeldahl nitrogen	EPA 351.5	BL05B20060	0.2	0.1	mg/L as N
Kjeldahl nitrogen	EPA 351.6	BL05B20155	0.2	0.1	mg/L as N
Kjeldahl nitrogen	EPA 351.7	BL05B20391	0.2	0.1	mg/L as N
Phosphorus	EPA 365.4	BL03B15329	0.02	0.01	mg/L
Phosphorus	EPA 365.5	BL04B16928	0.07	0.01	mg/L
Organic carbon	EPA 415.1 (D) Ox	BL05B18780	0.14	0.1	mg/L as C
Organic carbon	EPA 415.1 (T) Ox	BL05B18781	0.14	0.1	mg/L as C
pH	Std Method 2320 B	BL03B14948	6.2	0.1	pH Units
pH	Std Method 2320 B	BL03B14983	7	0.1	pH units
pH	Std Method 2320 B	BL04B16607	8	0.1	pH units
pH	Std Method 2320 B	BL04B17711	6.6	0.1	pH units
pH	Std Method 2320 B	BL05B19491	5.7	0.1	pH units
pH	Std Method 2320 B	BL05B19543	5.7	0.1	pH units

Table 8-6 Number of batches with method blank exceedances

Analyte	Method	Total batches	Batches with method blanks out of limits	Frequency of samples out of limits (%)
Alkalinity	Std Method 2320 B	114	2	1.80
Conductance (EC)	Std Method 2510-B	117	1	0.85
Kjeldahl Nitrogen	EPA 351.7	73	6	8.20
Phosphorus	EPA 365.4	75	2	2.60
Organic Carbon	EPA 415.1 (D) Ox	146	1	0.68
Organic Carbon	EPA 415.1 (T) Ox	148	1	0.67
pH	Std Method 2320 B	114	6	5.20

Table 8-7 LCS recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Kjeldahl nitrogen	EPA 351.2	BL03B15342	79	80-120
Kjeldahl nitrogen	EPA 351.2	BL04B16572	44.3	80-120
Kjeldahl nitrogen	EPA 351.2	BL04B18243	140	80-120
Organic carbon (total) by combustion	EPA 415.1 (T) cmbst	BL05B20106	116	80-120
Phosphorus (total)	EPA 365.4	BL04B15691	40.76	80-120
Phosphorus (total)	EPA 365.4	BL04B16928	125.34	85-115

Table 8-8 Frequency of QC batches with LCS recovery exceedances

Analyte	Total laboratory control samples	LCS recoveries out of limits	Frequency of samples out of limits (%)
Kjeldahl nitrogen	148	3	2.00
Organic carbon (total) by combustion	226	1	0.44
Phosphorus (total)	113	2	1.80

Table 8-9 Matrix spike recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Chloride	EPA 300.0 28d Hold	BL05B20442	136.9	80-120
Chloride	EPA 300.0 28d Hold	BL05B20442	137.4	80-120
Chloride	EPA 300.0 28d Hold	BL03B14955	-10	80-120
Kjeldahl nitrogen	EPA 351.2	BL04B15714	57	70-130
Kjeldahl nitrogen	EPA 351.2	BL04B15714	69	70-130
Kjeldahl nitrogen	EPA 351.2	BL04B16066	54.25	70-130
Kjeldahl nitrogen	EPA 351.2	BL04B16691	159.75	70-130
Kjeldahl nitrogen	EPA 351.2	BL04B17281	152	70-130
Kjeldahl nitrogen	EPA 351.2	BL04B17281	132.75	70-130
Kjeldahl nitrogen	EPA 351.2	BL04B17528	315.25	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B18658	64.25	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B19212	157.75	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B19852	147	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B19955	142.25	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B19955	161.5	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B20060	135.75	70-130
Kjeldahl nitrogen	EPA 351.2	BL05B20476	131.25	70-130
Phosphorus	EPA 365.4	BL03B15343	131	80.7-120.7
Phosphorus	EPA 365.4	BL03B15598	70	80.7-120.7
Phosphorus	EPA 365.4	BL03B15598	73	80.7-120.7
Phosphorus	EPA 365.4	BL04B15894	80	80.7-120.7
Phosphorus	EPA 365.4	BL04B15987	122	80.7-120.7
Phosphorus	EPA 365.4	BL04B15987	129	80.7-120.7
Phosphorus	EPA 365.4	BL04B16339	125	80.7-120.7
Phosphorus	EPA 365.4	BL05B18664	121	80.7-120.7
Phosphorus	EPA 365.4	BL05B18745	121	80.7-120.7
Phosphorus	EPA 365.4	BL05B19742	125	80.7-120.7
Phosphorus	EPA 365.4	BL05B19742	126	80.7-120.7
Sulfate	EPA 300.0 28d Hold	BL05B20442	124.4	80-120
Sulfate	EPA 300.0 28d Hold	BL05B20442	124.4	80-120

Table 8-10 Frequency of QC batches with matrix spike recovery exceedances

Analyte	Total matrix spikes	Matrix spike recoveries out of limits	Frequency of samples out of limits (%)
Chloride	1076	3	0.3
Kjeldahl nitrogen	120	14	11.6
Phosphorus	144	11	7.6
Sulfate	1004	2	0.2

Table 8-11 Matrix spike duplicate recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Kjeldahl nitrogen	EPA 351.2	BL03B15605	45.78	0-25
Kjeldahl nitrogen	EPA 351.2	BL04B16066	47.72	0-25
Kjeldahl nitrogen	EPA 351.2	BL04B16373	25.11	0-25
Kjeldahl nitrogen	EPA 351.2	BL04B16691	42.74	0-25
Kjeldahl nitrogen	EPA 351.2	BL04B16927	40.00	0-25
Kjeldahl nitrogen	EPA 351.2	BL04B17528	102.4	0-25
Phosphorus	EPA 365.4	BL03B15343	46.01	0-25
Phosphorus	EPA 365.4	BL04B16339	29.36	0-25
Phosphorus	EPA 365.4	BL05B18664	35.96	0-25

Table 8-12 Number of matrix spike duplicate recovery exceedances

Analyte	Total matrix spike duplicates	Matrix spike duplicate recoveries out of limits	Frequency of samples out of limits (%)
Kjeldahl nitrogen	60	6	10
Phosphorus	72	3	4.2

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Appendix A
Current State and Federal Drinking Water Standards

Available online at
http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm

or on CD inserted in report

Appendix B
Data Files

Available online at
http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm

or on CD inserted in report